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SITE ASSESSMENT WORK PLAN FOR BUILDINGS 358, 425 AND 436 NS MAYPORT FL
4/1/2000
TETRA TECH NUS

SITE ASSESSMENT WORKPLAN BUILDINGS 358, 425, AND 436

**Naval Station Mayport
Mayport, Florida**



**Southern Division
Naval Facilities Engineering Command
Contract Number N62467-94-D-0888
Contract Task Order CTO-0123**

APRIL 2000

**SITE ASSESSMENT WORKPLAN
BUILDINGS 358, 425, AND 436**

**NAVAL STATION MAYPORT
MAYPORT, FLORIDA**

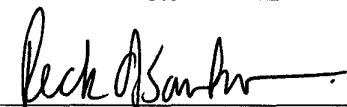
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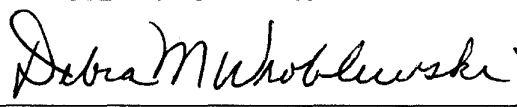
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1.0 INTRODUCTION

Tetra Tech NUS, Inc. (TtNUS) has prepared this Work Plan for the completion of a site assessment and submittal of a Site Assessment Report (SAR) for Buildings 358, 425, and 436 at Naval Station (NS) Mayport, Duval County, Florida. This Work Plan was prepared for the U.S. Navy (Navy) Southern Division (SOUTHDIR) Naval Facilities Engineering Command (NAVFACENGCOM) under Contract Task Order (CTO) 0123, for the Comprehensive Long-term Environmental Action Navy (CLEAN III) Contract Number N62467-94-D-0888.

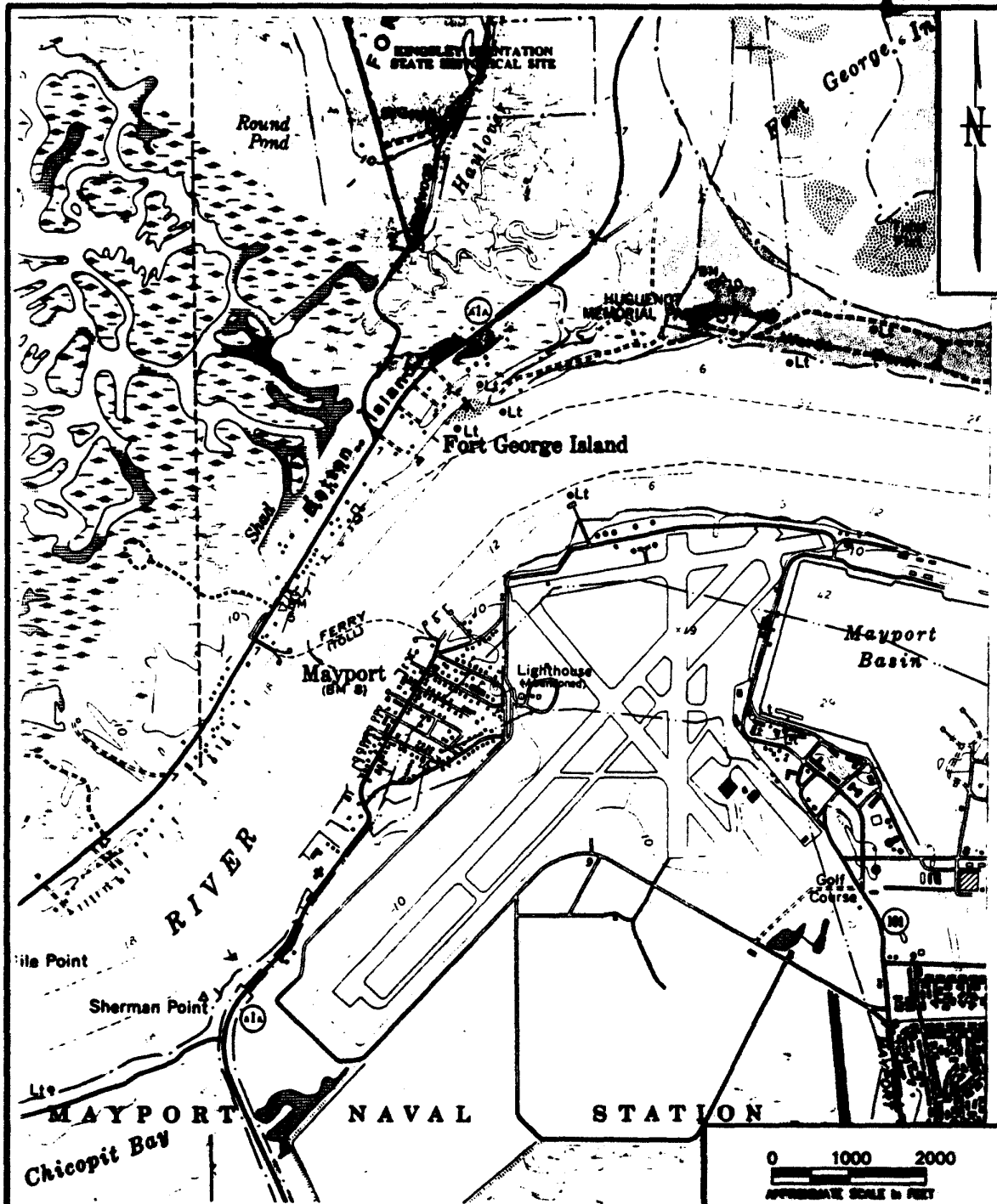
The Work Plan provides the rationale for performing field activities associated with collecting data to evaluate petroleum hydrocarbons in the subsurface at Buildings 358, 425, and 436 at NS Mayport. Data collected during the investigation at Buildings 358, 425, and 436 will be used to prepare a SAR for each location.

1.1 GENERAL SITE LOCATION

NS Mayport is located in eastern Duval County, approximately 16 miles northeast of downtown Jacksonville, Florida. NS Mayport is located in Section 38 of Township 1 South, Range 29 East. A base location map that shows its general location on the Mayport, Florida United States Geological Survey (USGS) Quadrangle (7.5 Minute Series) is provided as Figure 1-1. Buildings 358, 425, and 436 are depicted on the site location map, presented as Figure 1-2.

1.2 OBJECTIVE

The objective of the proposed field investigation at each site is to evaluate the presence or absence of petroleum hydrocarbons in subsurface soils and groundwater. The data collected during the investigations will be used to prepare a SAR for each location and to evaluate the need for a remedial action at the facility.



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BASE LOCATION MAP
U.S. NAVAL STATION
MAYPORT, FLORIDA

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2.0 SITE DESCRIPTION

The three source areas are located at different locations within the boundaries of NS Mayport. Building 358 is located at the Fleet Training Center on the northeastern edge of the base, Building 425 is located at the Bachelors Officers Quarters on the eastern edge of the base, and Building 436 is the Naval Air Station transmitter on the northwestern corner of the base. The assessment areas are located adjacent to the three buildings within the confines of the NS Mayport. Building 358 is the former location of a 10,000 aboveground storage tank (AST) and a 500-gallon gasoline underground storage tank (UST). Building 425 is the location of a 1,000-gallon AST used to store heating oil, and Building 436 is the location of a 1,000-gallon fuel oil AST.

3.0 SITE HISTORY

During the removal of the AST and UST at Building 358, petroleum impacted soil was encountered in the vicinity of the tanks. Soils were screened around the tanks with an Organic Vapor Analyzer (OVA) and showed elevated hydrocarbon vapors. However, laboratory analysis of the soil samples did not confirm the presence of petroleum impacted soils at concentrations above Florida Department of Environmental Protection (FDEP) target levels. The contractor did not delineate the impacted soil plume and removed only the soil incidental to the tank removal.

Building 425, located at the Bachelors Officer's Quarters, was the site of two releases. The first release occurred when the piping from a 1,000-gallon heating oil AST was ruptured by a utility contractor. The release occurred approximately 50 feet north of Building 425 and approximately 500 gallons of heating oil was reportedly released. Initial remedial actions were implemented immediately and approximately 65 cubic yards of soil was removed from the source area. The area was screened with an OVA to delineate the extent of petroleum impacted soils. Groundwater samples were not collected, however free product was collected at the bottom of the excavation. The second release at Building 425 occurred due to the failure of a float valve that caused heating oil to reverse flow direction and discharge along the western edge of Building 425, close to the foundation. Approximately 60 cubic yards of hydrocarbon impacted soil was removed during the initial remedial action. However, due to the proximity to the foundation of the building, all impacted soil was not removed. Laboratory analysis of the soil confirmed the presence of volatile organic aromatics (VOAs) above FDEP target levels.

Building 436 is the location of a 1,000-gallon fuel oil AST. During installation of the tank, a disconnection occurred in the piping system, which caused the release of heating fuel to an area along the southern edge of the building foundation. An unknown quantity of impacted soil was removed from the source area. The area in the vicinity of the release was screened with an OVA and hydrocarbon vapors were not detected.

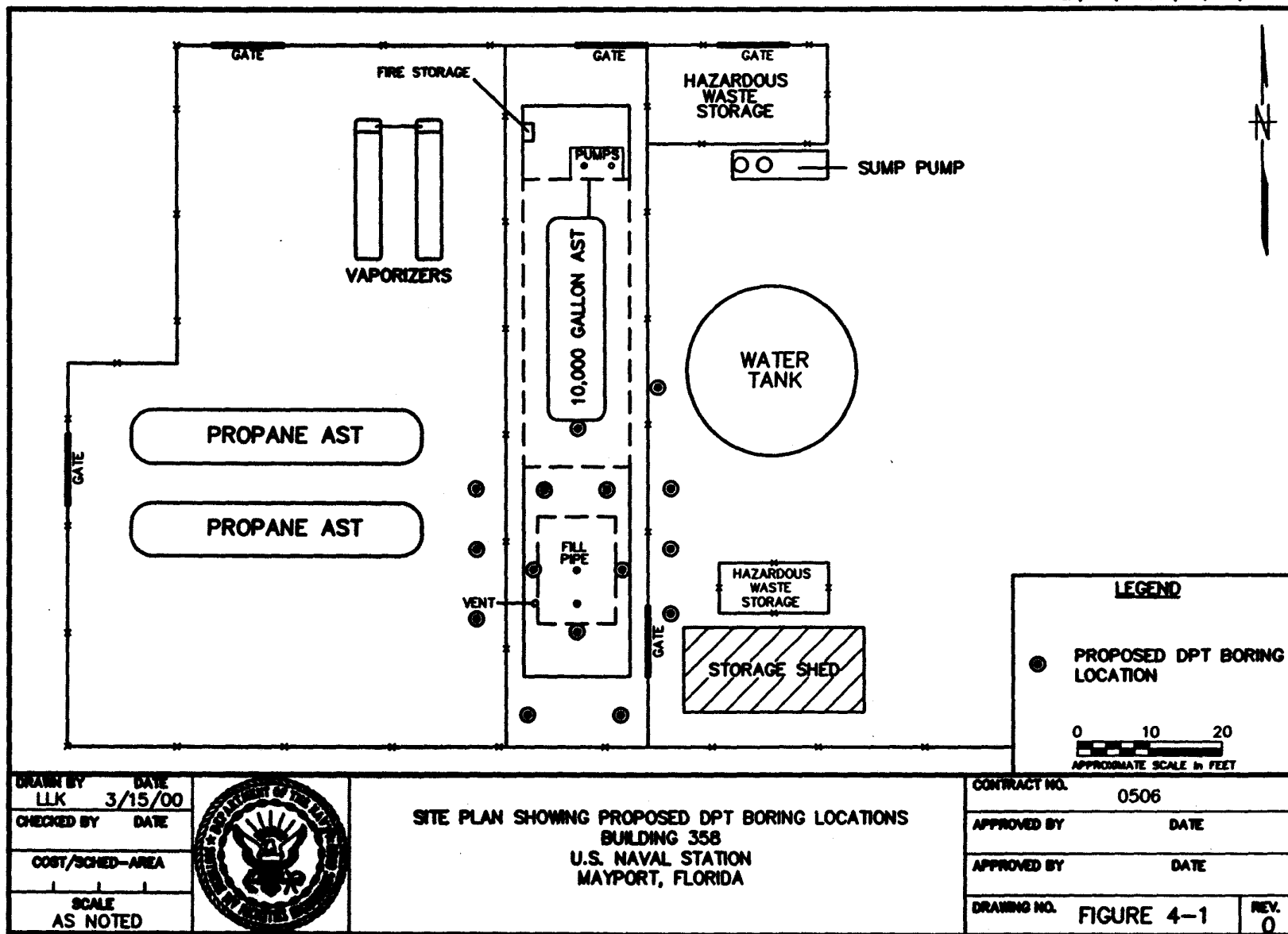
4.0 SCOPE OF PROPOSED ASSESSMENTS AND MONITORING

The proposed scope of work for assessment activities at Buildings 358, 425 and 436 will take place in two phases. Phase I will consist of installing direct-push technology (DPT) borings and analysis of soil and groundwater samples with a mobile laboratory to identify and delineate soil and groundwater contamination. Fieldwork for all three sites will be coordinated to reduce the number of mobilizations. Following the installation of the DPT borings and a preliminary delineation of the groundwater plume, the FDEP and SOUTHDIV will be notified of investigation results and recommendations will be made for the Phase II assessment. Phase II will consist of installation of monitoring wells to further delineate the extent of groundwater contamination at the sites. Hollow-stem auger (HSA) drilling equipment will be utilized to install the groundwater monitoring wells. Groundwater samples will be collected subsequent to monitoring well installation. Using a fixed-based laboratory, the samples will be analyzed to determine the extent of the dissolved phase groundwater contamination.

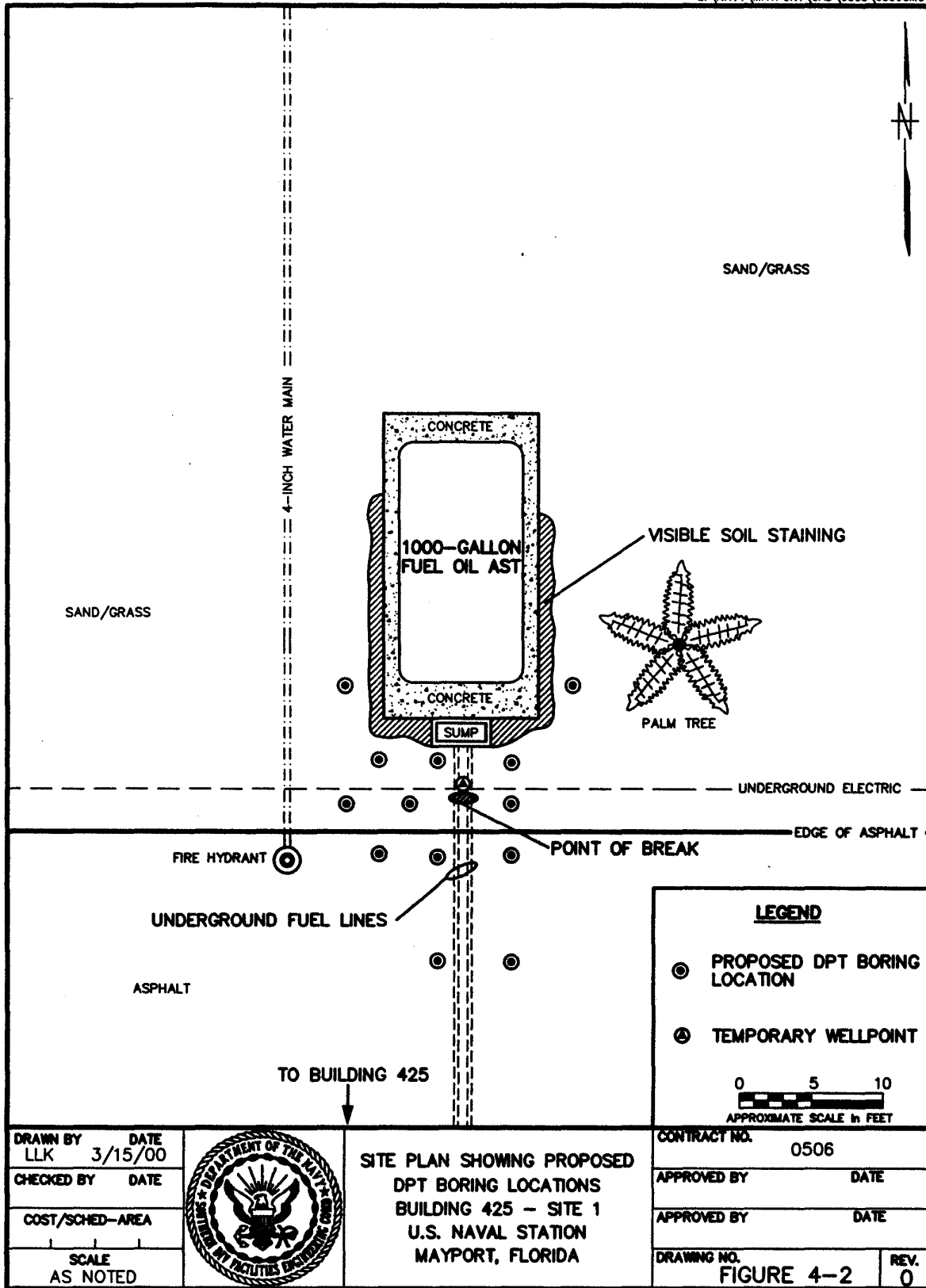
4.1 SOIL INVESTIGATION

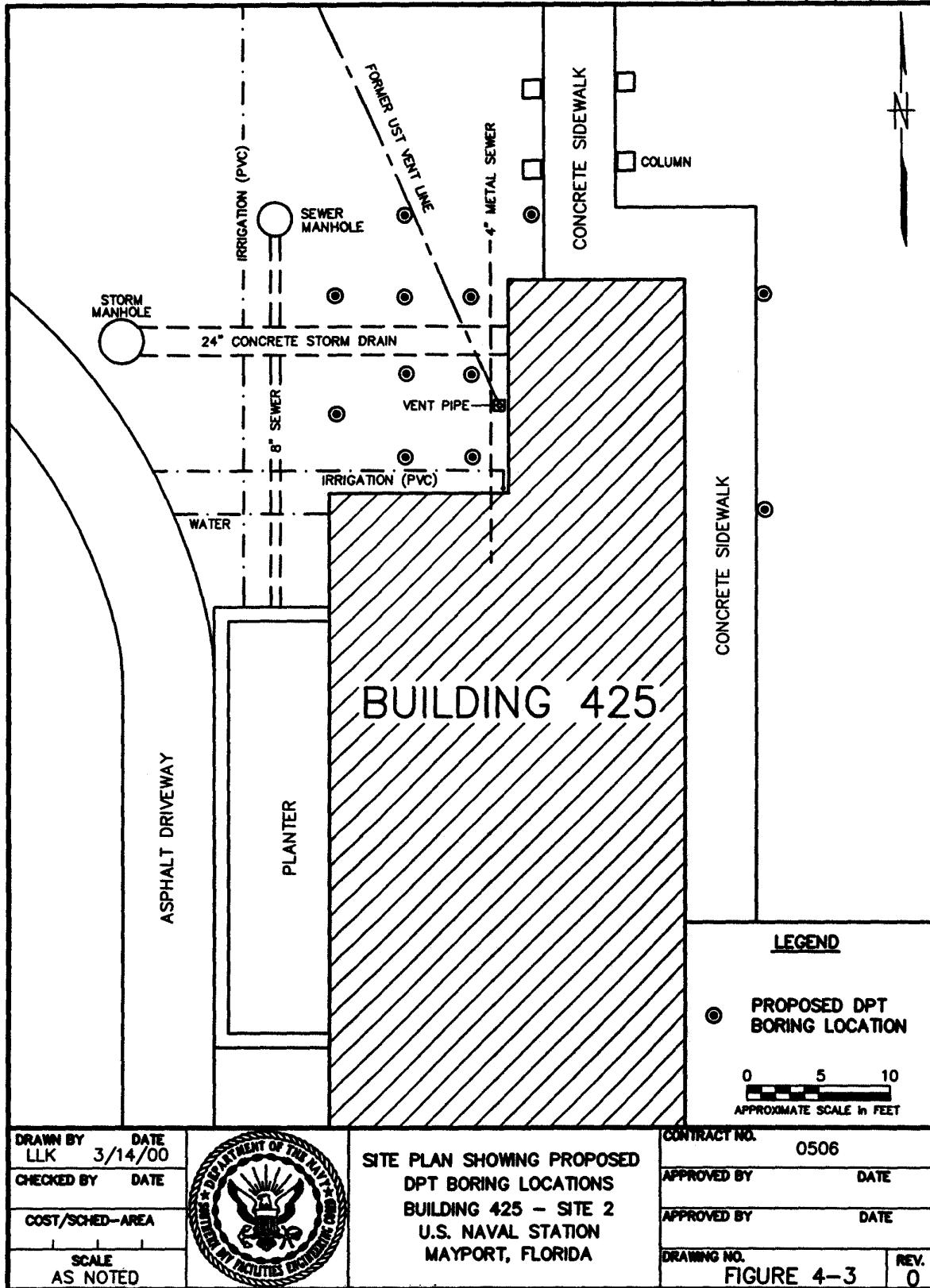
The hydrocarbon soil contamination assessment will be conducted during the Phase I DPT borings. At each site, three soil samples will be collected for analysis by a fixed based laboratory. Vadose zone soils will be screened for hydrocarbon vapors following procedures for headspace analysis as required by Chapter 62-770.200 FAC. A total of 15 DPT borings will be installed in each assessment area at Buildings 358 and 436, and 25 DPT borings will be installed at Building 425 due to the presence of two source areas. The approximate proposed locations of the DPT borings are depicted on Figures 4-1 through 4-4.

Soil samples sent to a fixed-based laboratory will be analyzed for constituents of the Kerosene Analytical Group (KAG), as defined in Chapter 62-770, FAC. Soil samples for Buildings 425 and 436 will also be analyzed for Waste Oil constituents. In addition, three soil samples will be analyzed for total organic carbon and one soil sample will be analyzed for grain size distribution and leachability parameters.

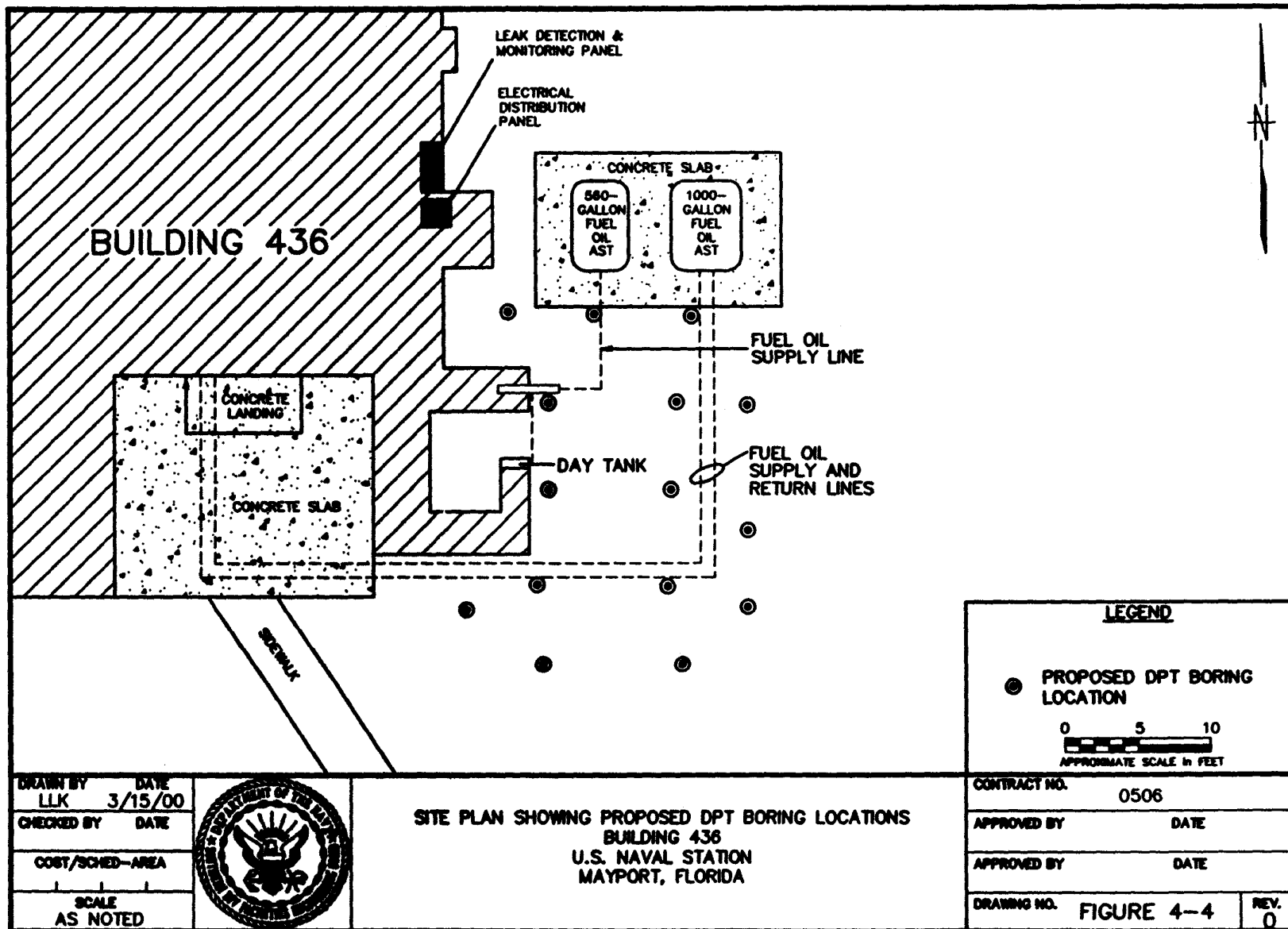


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The methodology for soil sampling will follow the revised procedures promulgated by the United States Environmental Protection Agency (USEPA) in Update III of SW-846 for sites contaminated with volatile organic compounds (VOCs). EnCore™ samplers will be used for soil collection and to transfer soil samples to the laboratory. This method assures the lowest loss of volatiles during collection and shipment of soils. In order for the laboratory to analyze for low level and high level VOCs, five EnCore™ samplers will be filled for each soil boring location. In addition, one 4-ounce jar will be filled for each soil boring location for analysis of moisture content. All soil samples will be shipped to the laboratory on the same day as collection to assure that the 48-hour holding time is not exceeded.

The on-site geologist will maintain a completed log of each boring. At a minimum, the boring log will contain the following information:

- Sample Numbers and Types
- Sample Depths
- Sample Recovery/Sample Interval
- Soil Density or Cohesiveness
- Soil Color
- Unified Soil Classification System (USCS) Material Description
- Presence of Free Product (if applicable)
- Filtered / Unfiltered OVA Readings

The site's lithology will be assessed from soil samples collected during the installation of the monitoring wells.

4.2 GROUNDWATER INVESTIGATION

It is anticipated that one upgradient, two downgradient, and one source area well will be installed to delineate the dissolved hydrocarbon plumes at each of the sites. Four additional wells will be installed at Building 425 due to the presence of two source areas. A vertical extent well will also be installed near the source area at each of the sites. The shallow water table monitoring wells will be installed approximately 15 feet below land surface (bls) and the vertical extent monitoring wells will be installed approximately 30 feet bls. The wells will be required to assess the horizontal and vertical extent of dissolved hydrocarbons at the three sites. The proposed monitoring well locations will be determined based on groundwater and

soil quality data collected from the DPT borings during Phase I. The proposed locations for monitoring wells will be discussed with the Navy and FDEP prior to the field investigation. Modifications to the proposed locations may be necessary due to underground and aboveground utilities.

4.2.1 Monitoring Well Installation

Permanent monitoring wells will be installed using hollow stem auger drilling techniques. These wells will be used to monitor water quality and evaluate the horizontal and vertical extent of contamination. Monitoring wells will be constructed of 2-inch inside diameter (ID) Schedule 40, flush-joint poly vinyl chloride (PVC) riser and flush-joint factory slotted well screen. Each section of casing and screen shall be National Sanitation Foundation (NSF) approved. Screen slot size shall be 0.01 inch. The shallow monitoring wells will be constructed with 10 feet of screen with the top of the screen interval positioned approximately 4 feet above the water table. The vertical extent monitoring well will be constructed with 5 feet of screen with the top of the screen interval positioned approximately 10 to 15 feet below the bottom of the shallow wells. After the borings are drilled to the desired depth, (6-inch minimum diameter boring for 2-inch ID wells), the well will be installed through the augers.

The lithology has been sufficiently characterized from previous investigations at NS Mayport. Therefore, a sieve analysis of the soils is not needed in determining the type of sand pack and screen slot size for well completion. Clean silica sand of U.S Standard Sieve Size No. 20/30 will be installed into the boring annulus around the well screen as the augers are withdrawn from the boring. Due to the expected shallow depths of the monitoring wells, (less than 15 feet), it is proposed that the sand pack be poured around the annulus from the top of the hole. The sand pack will be set from the bottom of the hole to approximately 1 foot above the top of the well screen. A minimum 1-foot thick bentonite pellet or fine sand seal will be installed above the sand pack. Borings that are not converted to monitoring wells will be backfilled with a Type I Portland cement/bentonite grout. The depths of all backfill materials will be constantly monitored during the well installation process by means of a weighted stainless steel or fiberglass tape. The position of the top of the screen interval, sand pack and bentonite seal may be adjusted as site conditions warrant (elevated water table, etc.)

Flush mounted steel well covers and manholes will be installed around the 2-inch ID wells. The manhole will consist of flush mounted 22-gauge steel, water resistant, welded box with 3/8-inch steel lid. A 2-foot by 2-foot by 6-inch thick concrete apron will be constructed around the manhole. The manhole shall be completed 2 inches above existing grade and the apron tapered to be flush with the existing grade at the

edges such that water will run off of the apron. A detail of a typical flush-mounted well is shown on Figure 4-5.

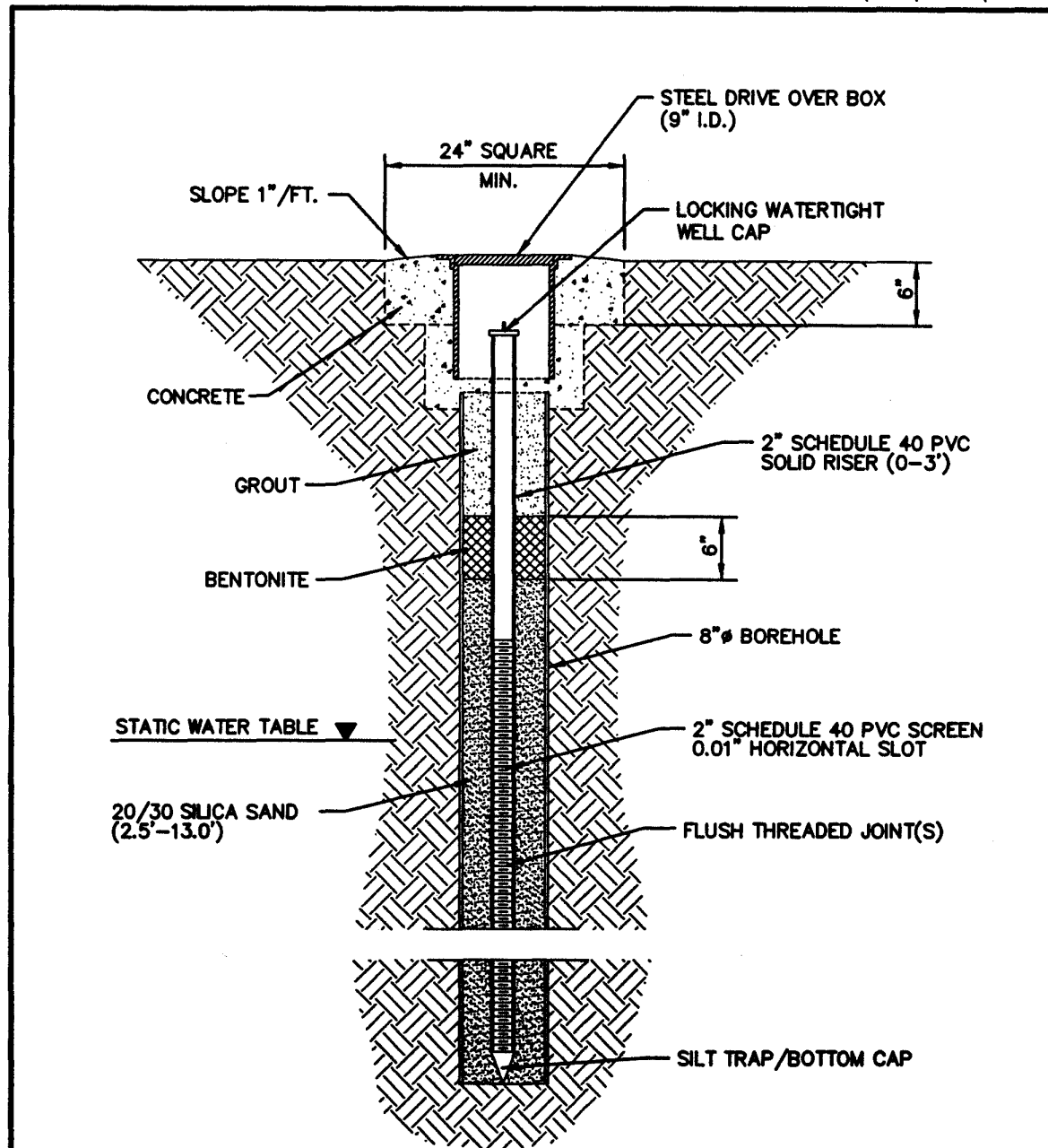
All locks supplied for the wells will be keyed alike. After installation, the ground surface, and the top of the PVC riser pipe will be surveyed to within 0.01-foot vertical accuracy using datum points as discussed previously in Section 4.0. A monitor well construction diagram will be completed for each well installed. A sample of the monitoring well construction form is provided in Appendix A.


The monitoring wells will be developed no sooner than 24 hours after installation to remove fine material from around the monitored interval of the well. Wells will be developed by bailing and surging, or by pumping, as determined by the field geologist. The pH, temperature, specific conductance, and turbidity measurements will be collected from the purge water. Wells will be developed up to a maximum of one hour or until these measurements become stable and the purge water is visibly clear. Water quality stabilization will be determined using the following criteria: temperature ($\pm 0.5^\circ\text{C}$), pH (± 0.1 unit), specific conductivity (± 10 $\mu\text{mhos/cm}$), and turbidity (within a 10 Nepelometric Turbidity Unit (NTU) range for 2 consecutive readings). Wells will be developed until approved by the field geologist.

4.2.2 Groundwater Sampling

Following installation of the monitoring wells, groundwater samples will be collected for analysis for KAG and Waste Oil constituents. In addition the samples will be field screened for dissolved oxygen, carbon dioxide, and ferrous iron. Laboratory analysis for nitrate, sulfate, sulfide and methane will also be performed on samples from selected monitoring wells.

Groundwater samples will be obtained from assessment monitoring wells at Buildings 358, 425 and 436 in accordance with TtNUS' Comprehensive Quality Assurance Plan (CompQAP) (FDEP Comp QA Plan No. 980038). Prior to obtaining samples, water levels and total well depths will be measured and the wells will be purged using a peristaltic pump and a low flow quiescent purging



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technique. Three to five well volumes will be purged. If wells are purged dry with less than three well volumes removed, the water level in the well will be allowed to recover at least 80 percent, then a sample will be collected. Field measurements of pH, temperature, specific conductance, and turbidity will be taken after each volume of water is purged. Stabilization of the above parameters is defined in the previous paragraphs. If these parameters do not stabilize after three volumes, up to five volumes will be removed. Before purging, a clear bailer or an oil water interface probe will be used to check for free product. No samples will be collected from a well that exhibits measurable free product. The thickness of the free product will be measured and recorded. Samples will be obtained using a peristaltic pump and a low flow quiescent sampling technique. The samples will be transferred directly into the appropriate (pre-preserved) sample bottles for analysis. Samples to be analyzed for volatile constituents shall be taken first and immediately sealed in the vial so that no headspace exists. The sample constituents to be analyzed are summarized in Table 4-1.

Table 4-1
Field Investigation Environmental Sample Summary
Buildings 358, 425 & 436
Naval Station
Mayport, Florida

Analyte	Proposed Method (1)	Env. Samples	Rinsate Blanks	IDW Samples(2)	Trip Blanks (Aqueous)	Total Samples
GROUNDWATER						
PPL-VOC, Non PPL-VOC	SW-846 8260B	22	1	1	1	25
PPL-SVOC	SW-846 8270C	22	1	1	0	24
PAH	SW-846 8310	22	1	1	0	24
LEAD	EPA 239.2	22	1	1	0	24
TRPH	FL-PRO	22	1	1	0	24
EDB	EPA 504.1	22	1	1	0	24
Anions	EPA 300	3	1	0	0	4
Sulfide	EPA 376.2	3	1	0	0	4
Methane	RSK SOPs 147 and 175	3	1	0	0	4
SOIL						
PPL-VOC	SW-846 8260B	9	0	1	0	10
PPL - SVOC	SW846 8270C	9	0	1	0	10
PAH	SW-846 8310	9	0	1	0	10
TRPH	FL-PRO	9	0	1	0	10
Total Lead	SW-846, 6010B	6	0	1	0	7
Ar, Cd and Cr	SW-846, 6010B	6	0	1	0	7
8 RCRA Metals	SW-846 6010B	0	0	1	0	1
Total Halogens (TOX)	SW-846 5050/0956	0	0	1	0	1
Total Organic Carbon (FOC)	ASTM D2974-87	9	0	0	0	9
Grain size distribution	ASTM D422	3	0	0	0	3
Leachability	SW846-1312 including 8021B, 8310.	3	0	1	0	4
TOTAL		204	9	15	1	229

Notes on following page.

Notes:

(1) Method referenced reflects FDEP requirements.

(2) IDW sample numbers based upon disposing of ten 55-gallon drums (1 composite sample) liquid and ten 55-gallon drums (1 composite sample) of soil.

All analyses are analyzed using standard 30-day laboratory turn around time.

4.2.3 Groundwater Level Measurements

Synoptic water level measurements will be taken from all monitoring wells at the sites. Static water level measurements will be measured from the north rim of the top of the PVC riser pipe using an electronic water level indicator. The newly installed wells shall be notched and marked so that the same point will be referenced for all measurements. The depth to water will be measured to the nearest 0.01 foot below the top of the PVC riser pipe. Water level measurements will be recorded to the nearest 0.01 foot in the appropriate field logbook.

4.3 AQUIFER TESTS

TtNUS will utilize existing groundwater data from previous aquifer tests performed at the base to determine hydraulic conductivity values of the aquifer at the three sites.

4.4 EQUIPMENT DECONTAMINATION

The equipment involved in field sampling activities will be decontaminated prior to and during drilling and sampling activities in accordance with TtNUS's Standard Operating Procedures (SOP) and CompQAP. This equipment includes drill rigs, downhole tools, augers, well casing and screens, and soil and water sampling equipment.

4.4.1 Major Equipment

All downhole drilling equipment used in the construction and sampling of permanent monitoring wells, including downhole drill and sampling tools shall be steam cleaned prior to beginning work, between boreholes, any time the drill rig leaves the drill site prior to completing a boring, and at the conclusion of the drill program.

These decontamination operations will consist of washing equipment using a high-pressure steam wash from a potable water supply and Alconox. Then the equipment will be rinsed with tap water. All decontamination activities will take place at a predetermined location. Additional requirements for drilling equipment decontamination can be found in SOP SA-7.1 included in Appendix B.

4.4.2 Sampling Equipment

All equipment such as trowels, bailers, and split spoon samplers used for collecting samples will be decontaminated prior to beginning field sampling and between sample locations. The following decontamination steps will be taken:

- Tap water and Alconox or Liquinox detergent rinse.
- Tap water rinse.
- If trace metals are to be sampled rinse with 10-15% reagent grade nitric acid (the nitric acid should not be used on stainless steel sampling equipment).
- Rinse thoroughly with de-ionized, analyte-free water.
- Rinse with isopropanol
- Rinse thoroughly with de-ionized, analyte-free water
- Air dry.
- Wrap equipment in aluminum foil until use.

Field meters such as pH, conductivity, and temperature instrument probes will be rinsed first with tap water, then with de-ionized, analyte-free water, and finally with the sample liquid.

4.5 WASTE HANDLING

Drill cuttings from drilling activities and purge water will be collected and containerized in Department of Transportation (DOT) approved (Specification 17C) 55-gallon drums. Each drum will be sealed, labeled and left at a drum staging area pending groundwater analytical results and/or composite waste sample results for disposal. A waste staging area will be established at the site to store investigative-derived waste (IDW) generated during the site assessment investigation. A lined decontamination pad will be constructed and used to collect the water from steam cleaning of drilling equipment. All decontamination

materials generated during the site investigation will be containerized for proper disposal. The disposal of IDW will be coordinated through NS Mayport.

4.6 SAMPLE HANDLING

Sample handling includes the field-related consideration concerning the selection of sample containers, preservatives, allowable holding times, and analysis requested. In addition, sample identification, packaging, and shipping will be addressed. All sample handling procedures will be in accordance with TtNUS's FDEP approved CompQAP No. 980038 dated August 25, 1999.

4.7 SAMPLE PACKAGING AND SHIPPING

Samples will be packaged and shipped in accordance with TtNUS' CompQAP. The field operations leader (FOL) will be responsible for completion of the following forms when samples are collected for shipping:

- Sample labels
- Chain-of-Custody labels
- Appropriate labels applied to shipping coolers
- Chain-of Custody Forms
- Federal Express Air Bills

TtNUS' CompQAP addresses the topics of containers and sample preservations. A summary of bottleware requirements, preservation requirements, and sample holding times are provided in Table 4-2.

Table 4-2
Summary of Analysis, Bottleware Requirements, Preservation Requirements, and Holding Times
Naval Station Mayport, Florida

Parameter	Analytical Method	Sample Container	Volume	Preservation	Maximum Holding Time (1)
Aqueous Samples					
VOHs, VOAs, and MTBE	SW-846 Method 8021B	Glass Volatile Vial	2 x 40 ml	Add HCl to pH < 2; Chill to 4 degrees Celsius	14 days
1,2-Dibromomethane	EPA Method 504.1	Glass Volatile Vial	40 ml	Add HCl to pH < 2; Chill to 4 degrees Celsius	28 days
PAHs	SW-846 Method 8310	Amber Glass	1 L	Add .008% Na ₂ S ₂ O ₃ ; Chill to 4 degrees Celsius	7 days until extraction; 40 days to analysis
Lead (Total and dissolved)	EPA Method 239.2	High Density Polyethylene	500 ml	Chill to 4 degrees Celsius	180 days
Arsenic, Cadmium, & Chromium	SW-846 6010B	High Density Polyethylene	250 ml	HNO ₃	180 days
Anions (Nitrate & Sulfate)	SW-846 9056	High Density Polyethylene	500 ml	Chill to 4 degrees Celsius	48 hours
Methane	RSK SOPs 147 and 175	Glass Volatile Vial	40 ml	Chill to 4 degrees Celsius	7 days
Sulfide	EPA 376.2	High Density Polyethylene	1 L	NaOH	7 days
TRPH	FL-PRO	Glass	1L	Add H ₂ SO ₄ to pH <2; Chill to 4 degrees Celsius	28 days

VOHs - Volatile Organic Halocarbons

VOAs - Volatile Organic Aromatics

MTBE - Methyl-tert-butyl-ether

PAHs - Polynuclear Aromatic Hydrocarbons

TRPH - Total Recoverable Petroleum Hydrocarbons

RCRA - Resource Conservation and Recovery Act

H₂SO₄ - Sulfuric acid

HCl - Hydrochloric acid

(1) - Holding time is measured from date of sample collection to date of sample analysis.

Table 4-2 (Continued)
Summary of Analysis, Bottleware Requirements, Preservation Requirements, and Holding Times
Naval Station Mayport, Florida

Parameter	Analytical Method	Sample Container	Volume	Preservation	Maximum Holding Time
Solid Samples					
VOHs, VOAs, and MTBE	SW-846 Method 8021B	EnCore Sampler	5 x 5g	Chill to 4 degrees Celsius; Lab to preserve within 48 hours of samples (2)	14 days
RCRA Metals	SW-846 Method 6010B/7000A series	Clear Wide Mouth Glass	4 ounces	Chill to 4 degrees Celsius	180 days; except mercury 28 days
TRPH	FL-PRO	Clear Wide Mouth Glass	4 ounces	Chill to 4 degrees Celsius	28 days
PAHs	SW-846 Method 8310	Clear Wide Mouth Glass	8 ounces	Chill to 4 degrees Celsius	14 days to extraction; 40 days to analysis
Total Halides	SW-846 Method 5050/9056	Clear Wide Mouth Glass	500 ml	Chill to 4 degrees Celsius	28 days

VOAs - Volatile Organic Aromatics

H₂SO₄ – Sulfuric acid

VOHs - Volatile Organic Halocarbons

HCl – Hydrochloric acid

MTBE - Methyl-tert-butyl-ether

(1) - Holding time is measured from date of sample collection to date of sample analysis.

PAHs - Polynuclear Aromatic Hydrocarbons

TRPH - Total Recoverable Petroleum Hydrocarbons

RCRA - Resource Conservation and Recovery Act

4.8 SAMPLE IDENTIFICATION

Each sample collected will be assigned a unique sample tracking number. The sample tracking number will consist of a three-segment, alpha-numeric code that identifies the building number (the Site), sample medium, location, the sampling event identifier or sample depth (in case of soil samples) and the QC designation, if applicable. Any other pertinent information regarding sample identification will be recorded in the field logbook.

The alpha-numeric coding to be used in the sample system is explained in the subsequent definitions:

NN (N or A - (Building Designation)

AA- (Medium)

AANN - (Location)

NNN (N)- (QC Designation, if applicable)

Character Type:

A = Alpha

N = Numeric

Medium:

GW = Groundwater sample from a monitoring well

SS = Subsurface soil sample taken via soil boring

TW = Temporary well groundwater sample

Sample Location:

Subsurface soil sample locations (SS) will correspond to the boring number (i.e., SB02)

Groundwater sample locations (GW) will correspond to the well number (i.e., 58-1)

Temporary well groundwater sample locations (TW) will correspond to the temporary well number (i.e., 58-TW1)

Sample Identifier:

For soil samples = Sample depth interval, in feet

For groundwater = Sampling round

QA Sample Designation:

D = Duplicate

F = Field Blank

B = Equipment Rinsate Blank

T = Trip Blank

For example, a groundwater sample collected from monitoring well MW-01 at Building 1360 UST would be designated as 1360-GW-MW01-001.

A duplicate sample from that same well would be 1360-GW-MW01-001D.

A subsurface soil sample taken from Monitoring Well Boring 01 at Building 1360 UST, at a depth of 4 to 6 feet bls would be 1360-SS-MW01-0406.

Information regarding sample labels to be attached before shipment to a laboratory is contained SOP SA-6.3 included in Appendix B. Examples of sample labels, chain of custody seals, and chain-of-custody forms are included in Appendix B.

4.9 SAMPLE CUSTODY

The chain-of-custody begins with the release of the sample bottles from the laboratory and must be documented and maintained from that point forward. To maintain custody of the sample bottles or samples, they must be in someone's physical possession, in a locked room or vehicle, or sealed with an intact custody seal. When the possession of the bottles or samples is transferred from one person to another it will be documented on the field logbook and on the chain-of-custody.

4.10 QUALITY CONTROL (QC) SAMPLES

In addition to periodic calibration of field equipment and appropriate documentation, quality control (QC) samples will be collected or generated during environmental sampling activities. QC samples may include field blanks, field duplicates, field replicates, and trip blanks. Each type of field QC sample is defined as follows:

Rinsate Blank - Rinsate blanks are obtained under representative field conditions by running organic free water through sample collection equipment (bailer, split-spoon, etc.) after decontamination and placing it in the appropriate containers for analysis. Rinsate blanks will be used to assess the effectiveness of decontamination procedures. If necessary, rinsate blanks may be collected for each type of non-dedicated sampling equipment used and will be submitted as shown in Table 4-1.

Field Duplicate - Field duplicate(s) are two water samples collected independently at a sample location during a single act of sampling under representative field conditions. Field duplicates sample frequencies are provided in Table 4-3. If necessary, the duplicates shall be analyzed for the same parameters in the laboratory as indicated in Table 4-1.

Trip Blanks - Trip blank(s) will be prepared at the laboratory facility and will accompany the VOA vials to the sampling site and back to the laboratory. Trip blanks are not required by the FDEP unless 10 or more volatiles samples are collected during a given sampling event. Trip blank sample frequency are provided in Table 4-3

TABLE 4-3
Quality Control Sample Frequency
Naval Station, Mayport, Florida

No. Samples	Precleaned Equipment BLK	Field cleaned Equipment BLK	Trip BLK (VOCs)	Duplicate
10+	Minimum of one then 5%	Minimum of one then 5%	one per cooler	minimum one then 10%
5-9	one*	one*	NR	one
< 5	one*	one*	NR	NR

NR = Not required

BLK = Blank

* Note: For 9 or fewer samples, a precleaned equipment blank or a field cleaned equipment blank is required. A field cleaned equipment blank must be collected if equipment is cleaned in the field.

4.11 FIELD MEASUREMENTS

Certain field measurements will be recorded during sampling activities including groundwater temperature, pH, specific conductance, and turbidity. Instruments used in the field to record this data and additional instruments will be calibrated according to the procedures described below.

4.11.1 Parameters

- Air monitoring - OVA
- Temperature - Temperature probe
- Specific conductance - Specific conductance meter
- pH - pH meter
- Turbidity - Turbidity meter
- Depth to water table - interface probe

4.11.2 Equipment Calibration

The electronic water-level indicator will be calibrated prior to mobilization and periodically at the discretion of the FOL. The remaining instruments will be calibrated daily and/or according to the manufacturer's operation manual.

Calibration will be documented on an Equipment Calibration Log as shown in Appendix A. During calibration, an appropriate maintenance check will be performed on each piece of equipment. If damaged or defective parts are identified during the maintenance check and it is determined that the damage could have an impact on the instrument's performance, the instrument will be removed from service until defective parts are repaired or replaced.

4.11.3 Equipment Maintenance

Measuring equipment used in environmental monitoring or analysis and test equipment used for calibration and maintenance shall be controlled by established procedures. Measuring equipment shall have an initial calibration and shall be recalibrated at scheduled intervals against certified standards.

TtNUS maintains a large inventory of sampling and measurement equipment. In the event that failed equipment cannot be repaired replacement equipment can be shipped to the site by overnight express carrier to minimize downtime.

4.12 RECORD KEEPING

In addition to chain-of-custody records associated with sample handling and packaging and shipping, certain standard forms will be completed for sample description and documentation. These shall include sample log sheets (for soil and groundwater samples), daily activity record and logbooks. An example of these forms can be found in Appendix A.

A bound/weatherproof field notebook shall be maintained by each sampling event leader. The field team leader or designee, shall record all information related to sampling or field activities. This information

may include sampling time, weather conditions, unusual events (e.g., well tampering), field measurements, descriptions of photographs, etc.

A site logbook shall be maintained by the FOL. The requirements of the logbook are referenced in Appendix B. This book will contain a summary of the day's activities and will reference the field notebooks when applicable.

Each field team leader who is supervising a drilling subcontractor activity must complete a Daily Activities Record (DAR). The DAR documents the activities and progress of the daily drilling activities. The information contained within this report is used for billing verification and progress reports. The driller's signature is required at the end of each working day to verify work accomplished, hour's worked, standby time and material used. An example of this form is provided in Appendix A.

At the completion of field activities, the FOL shall submit to the Project Manager all field records, data, field notebooks, logbooks, chain-of-custody receipts, sample log sheets, drilling logs, daily logs, etc.

4.13 SITE MANAGEMENT AND BASE SUPPORT

TtNUS will perform this project with support from the Navy. This section of the Work Plan describes the project contacts, support personnel, project milestones and time frames of all major events.

Throughout the duration of the investigation activities, work at NS Mayport be coordinated through SOUTHDIV and NS Mayport personnel. The primary contacts are as follows:

1. SOUTHDIV Engineer in Charge
Ms. Beverly Washington
(843) 820-5581
2. NS Mayport Engineering Officers
Mr. Jan Bouvier
(904) 270-6730

The following support functions will be provided by NS Mayport personnel:

- Assist TtNUS in locating underground utilities prior to the commencement of drilling operations.
- Provide existing engineering plans, drawings, diagram, files, etc., to facilitate evaluation of the Site under investigation.
- Provide all historical data, background geological and hydrogeological information, and initial site investigation documents.

NS Mayport personnel will aid in arranging the following:

- Personnel identification badges, vehicle passes, and/or entry permits.
- A secure staging area (approximately 1,000 square feet) for storing equipment and supplies.
- A supply (e.g., fire hydrant, stand pipe, etc.) of large quantities of potable water for equipment cleaning etc.
- As required, provide escorts for contract personnel working in secured areas.
- Establish a decontamination area and waste staging area located adjacent to or near the study area.

The project will be staffed with personnel from TtNUS' Deerfield Beach and Jacksonville, Florida offices. During field activities, TtNUS will provide a senior level geologist and/or staff geologist, and equipment technician(s).

Mr. Rick Ofsanko, is the Task Order Manager (TOM) for CTO 0123 and will be the primary point of contact. He is responsible for cost and schedule control as well as technical performance. Mr. Ofsanko

will serve as the TOM and will provide senior level review and oversight during field activities. Mr. Ofsanko will be the primary point of contact for the FOL.

4.13.1 Contingency Plan

In the event of problems that may be encountered during site activities, the SOUTHDIV point of contact will be notified immediately, followed by the TtNUS project manager and the NS Mayport personnel point of contact. The project manger will determine a course of action that will not interfere with the schedule or budget. All contingency plans will be approved through the SOUTHDIV point of contact before being enacted.

5.0 PROPOSED LABORATORY ANALYSIS

Groundwater samples and soil samples collected for laboratory analyses will be analyzed in accordance with parameters as identified in Chapter 62-770.800 (see Sections 5.1 and Section 5.2 below for specific sampling requirements regarding soil and groundwater).

5.1 SOIL INVESTIGATION

Three soil samples will be collected from each site and analyzed for VOC, Semi-Volatile Organic Compounds (SVOCs), Polynuclear Aromatic Hydrocarbons (PAHs), Total Recoverable Petroleum Hydrocarbons (TRPH) and Fraction of Organic Carbon (FOC). In addition three samples will be collected from Building 425 and 436 for total Lead, Arsenic, Cadmium and Chromium. Three samples, one from each site, will be analyzed for leachability parameters and grain size distribution. Parameters within these groups are identified on Table 4-1. The soil samples will be collected from the area of highest contamination within the soil boring as indicated by OVA screening.

5.2 GROUNDWATER INVESTIGATION

Groundwater samples will be collected from permanent monitoring wells at Buildings 358, 425 and 436. These samples will be analyzed for VOCs, SVOC, PAHs, Ethylene Dibromide (EDB), TRPH, Total Lead, Arsenic, Cadmium and Chromium. In addition, groundwater samples from each site will be analyzed for natural attenuation parameters, which include dissolved methane, anions, and sulfide.

A groundwater environmental sampling summary and a summary of IDW sample parameters are summarized in Table 4-1.

6.0 PROPOSED SCHEDULE

The assessment activities are proposed to begin in May 2000 and take approximately two months to complete the fieldwork. The SAR will be developed with the completion of the assessment activities and submitted to the Navy for review within 60 days of assessment completion.

7.0 REPORTS

Upon completion of all field work and laboratory analysis, a SAR will be written for each facility that summarizes the results of the investigation for submittal to the FDEP and the Navy. Basic site information including site Facility Identification Number, facility name and address, date closed, area, type of system and capacity will be provided. Also included in these reports will be graphical presentations of the groundwater screening results, and complete summaries of the soil and groundwater analytical results. The locations of the soil samples and monitoring wells will be presented on scaled figures. Boring logs, chain-of-custody forms, field forms, field screening results, and analytical reports will be included in Appendices of the reports. The SARs will recommend the completion of a remedial action plan, monitoring only plan, or no further action for each facility.

REFERENCES

Florida Department of Environmental Protection, July 15, 1998. New Soil Sampling Procedures and Recommended EPA Analytical Methods (per changes to USEPA SW-846) and Other Quality Assurance Issues for the Division of Waste Management.

Tetra Tech NUS, Inc., 1999 Revision. Comprehensive Quality Assurance Plan, FDEP COMP QA PLAN # 980038.

Appendix A
Standard Field Forms



FIELD ANALYTICAL LOG SHEET GEOCHEMICAL PARAMETERS

PAGE 1

Tetra Tech NUS, Inc.

Page __ of __

Project Site Name: _____					Sample ID No.: _____				
Project No.: _____					Sample Location: _____				
Sampled By: _____					Duplicate: <input type="checkbox"/>				
Field Analyst: _____					Blank: <input type="checkbox"/>				
Field Form Checked as per QA/QC Checklist (Initials): _____									
SAMPLING DATA:									
Date: _____	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (%)	Other	
Time: _____									
Method: _____									
SAMPLE COLLECTION/ANALYSIS INFORMATION:									
ORP (EH) (+/- mv): _____					Electrode Make & Model: _____				
Reference Electrode (circle one): Silver-Silver Chloride / Calomel / Hydrogen									
Dissolved Oxygen:									
Equipment: HACH Digital Titrator OX-DT		CHEMetrics (Range: _____ mg/L)			Analysis Time: _____				
Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration		
<input type="checkbox"/>	1-5 mg/L	200 ml	0.200 N	0.01	_____	x 0.01	=	mg/L	
<input type="checkbox"/>	2-10 mg/L	100 ml	0.200 N	0.02	_____	x 0.02	=	mg/L	
CHEMetrics: _____ mg/L									
Notes: _____									
Alkalinity:									
Equipment: HACH Digital Titrator AL-DT		CHEMetrics (Range: _____ mg/L)			Analysis Time: _____				
Filtered: <input type="checkbox"/>									
Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration		
<input type="checkbox"/>	10-40 mg/L	100 ml	0.1600 N	0.1	_____ & _____	x 0.1	=	mg/L	
<input type="checkbox"/>	40-160 mg/L	25 ml	0.1600 N	0.4	_____ & _____	x 0.4	=	mg/L	
<input type="checkbox"/>	100-400 mg/L	100 ml	1.600 N	1.0	_____ & _____	x 1.0	=	mg/L	
<input type="checkbox"/>	200-800 mg/L	50 ml	1.600 N	2.0	_____ & _____	x 2.0	=	mg/L	
<input type="checkbox"/>	600-2000 mg/L	20 ml	1.600 N	5.0	_____ & _____	x 5.0	=	mg/L	
<input type="checkbox"/>	1000-4000 mg/L	10 ml	1.600 N	10.0	_____ & _____	x 10.0	=	mg/L	
CHEMetrics: _____ mg/L									
Notes: _____									
Carbon Dioxide:									
Equipment: HACH Digital Titrator CA-DT		CHEMetrics (Range: _____ mg/L)			Analysis Time: _____				
Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration		
<input type="checkbox"/>	10-50 mg/L	200 ml	0.3636 N	0.1	_____	x 0.1	=	mg/L	
<input type="checkbox"/>	20-100 mg/L	100 ml	0.3636 N	0.2	_____	x 0.2	=	mg/L	
<input type="checkbox"/>	100-400 mg/L	200 ml	3.636 N	1.0	_____	x 1.0	=	mg/L	
<input type="checkbox"/>	200-1000 mg/L	100 ml	3.636 N	2.0	_____	x 2.0	=	mg/L	
CHEMetrics: _____ mg/L									
Notes: _____									
Standard Additions: <input type="checkbox"/> Titrant Molarity: _____ Digits Required: 1st.: _____ 2nd.: _____ 3rd.: _____									
Carbon Dioxide:									
Equipment: HACH Digital Titrator CA-DT		CHEMetrics (Range: _____ mg/L)			Analysis Time: _____				
Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration		
<input type="checkbox"/>	10-50 mg/L	200 ml	0.3636 N	0.1	_____	x 0.1	=	mg/L	
<input type="checkbox"/>	20-100 mg/L	100 ml	0.3636 N	0.2	_____	x 0.2	=	mg/L	
<input type="checkbox"/>	100-400 mg/L	200 ml	3.636 N	1.0	_____	x 1.0	=	mg/L	
<input type="checkbox"/>	200-1000 mg/L	100 ml	3.636 N	2.0	_____	x 2.0	=	mg/L	
CHEMetrics: _____ mg/L									
Notes: _____									
Standard Additions: <input type="checkbox"/> Titrant Molarity: _____ Digits Required: 1st.: _____ 2nd.: _____ 3rd.: _____									



FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

PAGE 2

Tetra Tech NUS, Inc.

Page ___ of ___

Project Site Name: _____	Sample ID No.: _____
Project No.: _____	Sample Location: _____
Sampled By: _____	Duplicate: <input type="checkbox"/>
Field Analyst: _____	Blank: <input type="checkbox"/>
Field Form Checked as per QA/QC Checklist (initials): <input type="checkbox"/>	

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Sulfide (S^{2-}):

Equipment: DR-700 DR-8 __ HS-WR Color Wheel Other: _____ Analysis Time: _____
Program/Module: 610nm 93
Concentration: _____ mg/L Filtered: ☐
Notes: _____

Sulfate (SO_4^{2-}):

Equipment: DR-700 DR-8 __ Other: _____ Analysis Time: _____
Program/Module: 91
Concentration: _____ mg/L Filtered: ☐
Standard Solution: ☐ Results: _____
Standard Additions: ☐ Digits Required: 0.1ml: _____ 0.2ml: _____ 0.3ml: _____
Notes: _____

Nitrite (NO_2^-N):

Equipment: DR-700 DR-8 __ Other: _____ Analysis Time: _____
Program/Module: 60
Concentration: _____ mg/L Filtered: ☐
Reagent Blank Correction: ☐
Standard Solution: ☐ Results: ☐
Notes: _____

Nitrate (NO_3^-N):

Equipment: DR-700 DR-8 __ Other: _____ Analysis Time: _____
Program/Module: 55
Concentration: _____ mg/L Filtered: ☐
Nitrite Interference Treatment: ☐
Standard Solution: ☐ Results: _____ Reagent Blank Correction: ☐
Standard Additions: ☐ Digits Required: 0.1ml: _____ 0.2ml: _____ 0.3ml: _____
Notes: _____



FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS

PAGE 3

Tetra Tech NUS, Inc.

Page of

Project Site Name: _____

Sample ID No.: _____

Project No.: _____

Sample Location: _____

Sampled By: _____

Duplicate: ☐

Field Analyst: _____

Blank: ☐

Field Form Checked as per QA/QC Checklist (initials): ☐

SAMPLE COLLECTION/ANALYSIS INFORMATION:

Manganese (Mn^{2+}):

Equipment: DR-700 DR-8 HACH MN-5 Other: _____ Analysis Time: _____

Program/Module: 525nm 41

Concentration: _____ mg/L

Filtered: ☐

Digestion: ☐

Standard Solution: ☐

Results: _____

Reagent Blank Correction: ☐

Standard Additions: ☐

Digits Required: 0.1ml: _____ 0.2ml: _____ 0.3ml: _____

Notes: _____

Ferrous Iron (Fe^{2+}):

Equipment: DR-700 DR-8 IR-18C Color Wheel Other: _____ Analysis Time: _____

Program/Module: 500nm 33

Concentration: _____ mg/L

Filtered: ☐

Notes: _____

Hydrogen Sulfide (H_2S):

Equipment: HS-C Other: _____ Analysis Time: _____

Concentration: _____ mg/L Exceeded 5.0 mg/L range on color chart: ☐

Notes: _____

QA/QC Checklist:

All data fields have been completed as necessary: ☐

Correct measurement units are cited in the SAMPLING DATA block: ☐

Values cited in the SAMPLING DATA block are consistent with the Groundwater Sample Log Sheet: ☐

Multiplication is correct for each *Multiplier* table: ☐

Final calculated concentration is within the appropriate *Range Used* block: ☐

Alkalinity *Relationship* is determined appropriately as per manufacturer (HACH) instructions: ☐

QA/QC sample (e.g., Std. Additions, etc.) frequency is appropriate as per the project planning documents: ☐

Nitrite Interference treatment was used for Nitrate test if Nitrite was detected: ☐

Title block on each page of form is initialized by person who performed this QA/QC Checklist: ☐



Project Name: _____ Project No.: _____
 Location: _____ Personnel: _____
 Weather Conditions: _____ Measuring Device: _____
 Tidally Influenced: Yes ____ No ____ Remarks: _____

[illegible]

* All measurements to the nearest 0.01 foot

Page ____ of ____

Project Site Name: _____ Project No.: _____ <input type="checkbox"/> Surface Soil <input type="checkbox"/> Subsurface Soil <input type="checkbox"/> Sediment <input type="checkbox"/> Other: _____ <input type="checkbox"/> QA Sample Type: _____	Sample ID No.: _____ Sample Location: _____ Sampled By: _____ C.O.C. No.: _____ Type of Sample: <input type="checkbox"/> Low Concentration <input type="checkbox"/> High Concentration
---	--

GRAB SAMPLE DATA:			
Date: _____	Depth Interval	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time: _____			
Method: _____			
Monitor Reading (ppm): _____			

COMPOSITE SAMPLE DATA:				
Date: _____	Time	Depth Interval	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method: _____				
Monitor Readings (Range in ppm): _____				

SAMPLE COLLECTION INFORMATION:			
Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:	MAP:

Circle if Applicable:		Signature(s):
MS/MSD	Duplicate ID No.:	



EQUIPMENT CALIBRATION LOG

INSTRUMENT NAME/MODEL: _____

MANUFACTURER: _____

SERIAL NUMBER: _____

[illegible]



Page ____ of ____

Well: _____ Depth to Bottom (ft.): _____ Responsible Personnel: _____
 Site: _____ Static Water Level Before (ft.): _____ Drilling Co.: _____
 Date Installed: _____ Static Water Level After (ft.): _____ Project Name: _____
 Date Developed: _____ Screen Length (ft.): _____ Project Number: _____
 Dev. Method: _____ Specific Capacity: _____
 Pump Type: _____ Casing ID (in.): _____

[illegible]



**MONITORING WELL MATERIALS
CERTIFICATE OF CONFORMANCE**

Well Designation: _____
Site Name: _____
Date Installed: _____
Project Name: _____

Site Geologist: _____
Drilling Company: _____
Driller: _____
Project Number: _____

Material	Brand/Description	Source/Supplier	Sample Collected ?
Well Casing			
Well Screen			
End Cap			
Drilling Fluid			
Drilling Fluid Additives			
Backfill Material			
Annular Filter Pack			
Bentonite Seal			
Annular Grout			
Surface Cement			
Protective Casing			
Paint			
Rod Lubricant			
Compressor Oil			

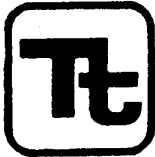
To the best of my knowledge, I certify that the above described materials were used during installation of this monitoring well.

Signature of Site Geologist: _____



Appendix B

Standard Operating Procedures



TETRA TECH NUS, INC.

STANDARD OPERATING PROCEDURES

Subject

GROUNDWATER MONITORING WELL INSTALLATION

Number

GH-2.8

Page

1 of 12

Effective Date

06/99

Revision

2

Applicability

Tetra Tech NUS, Inc.

Prepared

Approved

D. Senovich

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1.0 PURPOSE

This procedure provides general guidance and information pertaining to proper monitoring well design, installation, and development.

2.0 SCOPE

This procedure is applicable to the construction of monitoring wells. The methods described herein may be modified by project-specific requirements for monitoring well construction. In addition, many regulatory agencies have specific regulations pertaining to monitoring well construction and permitting. These requirements must be determined during the project planning phases of the investigation, and any required permits must be obtained before field work begins. Innovative monitoring well installation techniques, which typically are not used, will be discussed only generally in this procedure.

3.0 GLOSSARY

Monitoring Well - A well which is screened, cased, and sealed which is capable of providing a groundwater level and groundwater sample representative of the zone being monitored. Some monitoring wells may be constructed as open boreholes.

Piezometer - A pipe or tube inserted into the water bearing zone, typically open to water flow at the bottom and to the atmosphere at the top, and used to measure water level elevations. Piezometers may range in size from 1/2-inch-diameter plastic tubes to well points or monitoring wells.

Potentiometric Surface - The surface representative of the level to which water will rise in a well cased to the screened aquifer.

Well Point (Drive Point) - A screened or perforated tube (Typically 1-1/4 or 2 inches in diameter) with a solid, conical, hardened point at one end, which is attached to a riser pipe and driven into the ground with a sledge hammer, drop weight, or mechanical vibrator. Well points may be used for groundwater injection and recovery, as piezometers (i.e., to measure water levels) or to provide groundwater samples for water quality data.

4.0 RESPONSIBILITIES

Driller - The driller provides adequate and operable equipment, sufficient quantities of materials, and an experienced and efficient labor force capable of performing all phases of proper monitoring well installation and construction. The driller may also be responsible for obtaining, in advance, any required permits for monitoring well installation and construction.

Field Geologist - The field geologist supervises and documents well installation and construction performed by the driller, and insures that well construction is adequate to provide representative groundwater data from the monitored interval. Geotechnical engineers, field technicians, or other suitable trained personnel may also serve in this capacity.

Subject GROUNDWATER MONITORING WELL INSTALLATION	Number GH-2.8	Page 3 of 12
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5.0 PROCEDURES

5.1 Equipment/Items Needed

Below is a list of items that may be needed when installing a monitoring well or piezometer:

- Health and safety equipment as required by the Site Safety Officer.
- Well drilling and installation equipment with associated materials (typically supplied by the driller).
- Hydrogeologic equipment (weighted engineer's tape, water level indicator, retractable engineers rule, electronic calculator, clipboard, mirror and flashlight - for observing downhole activities, paint and ink marker for marking monitoring wells, sample jars, well installation forms, and a field notebook).
- Drive point installation tools (sledge hammer, drop hammer, or mechanical vibrator; tripod, pipe wrenches, drive points, riser pipe, and end caps).

5.2 Well Design

The objectives and intended use for each monitoring well must be clearly defined before the monitoring system is designed. Within the monitoring system, different monitoring wells may serve different purposes and, therefore, require different types of construction. During all phases of the well design, attention must be given to clearly documenting the basis for design decisions, the details of well construction, and the materials used. The objectives for installing the monitoring wells may include:

- Determining groundwater flow directions and velocities.
- Sampling or monitoring for trace contaminants.
- Determining aquifer characteristics (e.g., hydraulic conductivity).

Siting of monitoring wells shall be performed after a preliminary estimation of the groundwater flow direction. In most cases, groundwater flow directions and potential well locations can be determined by an experienced hydrogeologist through the review of geologic data and the site terrain. In addition, data from production wells or other monitoring wells in the area may be used to determine the groundwater flow direction. If these methods cannot be used, piezometers, which are relatively inexpensive to install, may have to be installed in a preliminary investigative phase to determine groundwater flow direction.

5.2.1 Well Depth, Diameter, and Monitored Interval

The well depth, diameter, and monitored interval must be tailored to the specific monitoring needs of each investigation. Specification of these items generally depends on the purpose of the monitoring system and the characteristics of the hydrogeologic system being monitored. Wells of different depth, diameter, and monitored interval can be employed in the same groundwater monitoring system. For instance, varying the monitored interval in several wells, at the same location (cluster wells) can help to determine the vertical gradient and the depths at which contaminants are present. Conversely, a fully penetrating well is usually not used to quantify or vertically locate a contaminant plume, since groundwater samples collected in wells that are screened over the full thickness of the water-bearing zone will be representative of average conditions across the entire monitored interval. However, fully penetrating wells can be used to establish the existence of contamination in the water-bearing zone. The well diameter desired depends upon the hydraulic characteristics of the water-bearing zone, sampling requirements, drilling method and cost.

Subject GROUNDWATER MONITORING WELL INSTALLATION	Number GH-2.8	Page 4 of 12
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The decision concerning the monitored interval and well depth is based on the following (and possibly other) information:

- The vertical location of the contaminant source in relation to the water-bearing zone.
- The depth, thickness and uniformity of the water-bearing zone.
- The anticipated depth, thickness, and characteristics (e.g., density relative to water) of the contaminant plume.
- Fluctuation in groundwater levels (due to pumping, tidal influences, or natural recharge/discharge events).
- The presence and location of contaminants encountered during drilling.
- Whether the purpose of the installation is for determining existence or non-existence of contamination or if a particular stratigraphic zone is being investigated.
- The analysis of borehole geophysical logs.

In most situations where groundwater flow lines are horizontal, depending on the purpose of the well and the site conditions, monitored intervals are 20 feet or less. Shorter screen lengths (5 feet or less) are usually required where flow lines are not horizontal, (i.e., if the wells are to be used for accurate measurement of the potentiometric head at a specific point).

Many factors influence the diameter of a monitoring well. The diameter of the monitoring well depends on the application. In determining well diameter, the following needs must be considered:

- Adequate water volume for sampling.
- Drilling methodology.
- Type of sampling device to be used.
- Costs.

Standard monitoring well diameters are 2, 4, 6, or 8 inches. Drive points are typically 1-1/4 or 2 inches in diameter. For monitoring programs which require screened monitoring wells, either a 2-inch or 4-inch-diameter well is preferred. Typically, well diameters greater than 4 inches are used in monitoring programs in which open-hole bedrock monitoring wells are used. With smaller diameter wells, the volume of stagnant water in the well is minimized, and well construction costs are reduced; however, the sampling devices that can be used are limited.

In specifying well diameter, sampling requirements must be considered (up to a total of 4 gallons of water may be required for a single sample to account for full organic and inorganic analyses, and split samples), particularly if the monitored formation is known to be a low-yielding formation. The unit volume of water contained within a monitoring well is dependent on the well diameter as follows:

Casing Inside Diameter (inch)	Standing Water Length to Obtain 1 Gallon Water (Feet)
2	6.13
4	1.53
6	0.68

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If a well recharges quickly after purging, then well diameter may not be an important factor regarding sample volume requirements.

Pumping tests for determining aquifer characteristics may require larger diameter wells (for installation of high capacity pumps); however, in small-diameter wells in-situ permeability tests can be performed during drilling or after well installation is completed.

5.2.2 Riser Pipe and Screen Materials

Well materials are specified by diameter, type of material, and thickness of pipe. Well screens require an additional specification of slot size. Thickness of pipe is referred to as "Schedule" for polyvinyl chloride (PVC) casing and is usually Schedule 40 (thinner wall) or 80 (thicker wall). Steel pipe thickness is often referred to as "Strength". Standard Strength is usually adequate for monitoring well purposes. With larger diameter pipe, the wall thickness must be greater to maintain adequate strength. The required thickness is also dependent on the method of installation; risers for drive points require greater strength than wells installed inside drilled borings.

The selection of well screen and riser materials depends on the method of drilling, the type of subsurface materials the well penetrates, the type of contamination expected, and natural water quality and depth. Cost and the level of accuracy required are also important. The materials generally available are Teflon, stainless steel, PVC galvanized steel, and carbon steel. Each has advantages and limitations (see Attachment A of this guideline for an extensive presentation on this topic). The two most commonly used materials are PVC and stainless steel. Properties of these two materials are compared in Attachment B. Stainless steel is a good choice where trace metals or organic sampling is required; however, costs are high. Teflon materials are extremely expensive, but are relatively inert and provide the least opportunity for water contamination due to well materials. PVC has many advantages, including low cost, excellent availability, light weight, ease of manipulation, and widespread acceptance. The crushing strength of PVC may limit the depth of installation, but the use of Schedule 80 materials may overcome some of the problems associated with depth. However, the smaller inside diameter of Schedule 80 pipe may be an important factor when considering the size of bailers or pumps required for sampling or testing. Due to this problem, the minimum well pipe size recommended for Schedule 80 wells is 4-inch I.D.

Screens and risers may have to be decontaminated before use because oil-based preservatives and oil used during thread cutting and screen manufacturing may contaminate samples. Metal pipe may corrode and release metal ions or chemically react with organic constituents, but this is considered a minor issue. Galvanized steel is not recommended where samples may be collected for metals analyses, as zinc and cadmium levels in groundwater samples may become elevated from leaching of the zinc coating.

Threaded, flush-joint casing is most often preferred for monitoring well applications. PVC, Teflon, and steel can all be obtained with threaded joints. Welded-joint steel casing is also acceptable. Glued PVC may release organic contaminants into the well, and therefore, should not be used if the well is to be sampled for organic constituents.

When the water-bearing zone is in consolidated bedrock, such as limestone or fractured granite, a well screen is often not necessary (the well is simply an open hole in bedrock). Unconsolidated materials, such as sands, clay, and silts require a screen. A screen slot size of 0.010 or 0.020 inch is generally used when a screen is necessary, and the annular borehole space around the screened interval is artificially packed with an appropriately sized sand, selected based on formation grain size. The slot size controls the quantity of water entering the well and prevents entry of natural materials or sand pack. The screen shall pass no more than 10 percent of the pack material, or in-situ aquifer material. The site geologist

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shall specify the combination of screen slot size and sand pack which will be compatible with the water-bearing zone, to maximize groundwater inflow and minimize head losses and movement of fines into the wells. For example, as a standard procedure, a Morie No. 1 or No. 10 to No. 20 U.S. Standard Sieve size filter pack is typically appropriate for a 0.020-inch slot screen; however, a No. 20 to No. 40 U.S. Standard Sieve size filter pack is typically appropriate for a 0.010-inch slot screen.

5.2.3 Annular Materials

Materials placed in the annular space between the borehole and riser pipe and screen include a sand pack when necessary, a bentonite seal, and cement-bentonite grout. The sand pack is usually a medium-to coarse-grained poorly graded, silica sand and should relate to the grain size of the aquifer sediments. The quantity of sand placed in the annular space is dependent upon the length of the screened interval, but should always extend at least 1 foot above the top of the screen. At least 1 to 3 feet of bentonite pellets or equivalent shall be placed above the sand pack. Cement-bentonite grout (or equivalent) is then placed to extent from the top of the bentonite pellets to the ground surface.

On occasion, and with the concurrence of the involved regulatory agencies, monitoring wells may be packed naturally (i.e., no artificial sand pack installed). In this case, the natural formation material is allowed to collapse around the well screen after the well is installed. This method has been used where the formation material itself is a relatively uniform grain size, or when artificial sand packing is not possible due to borehole collapse.

Bentonite expands by absorbing water and provides a seal between the screened interval and the overlying portion of the annular space and formation. Cement-bentonite grout is placed on top of the bentonite pellets, extending to the surface. The grout effectively seals the remaining borehole annulus and eliminates the possibility for surface infiltration reaching the screened interval. Grouting also replaces material removed during drilling and prevents hole collapse and subsidence around the well. A tremie pipe should be used to introduce grout from the bottom upward, to prevent bridging, and to provide a better seal. In shallow boreholes that don't collapse, it may be more practical to pour the grout from the surface without a tremie pipe.

Grout is a general term which has several different connotations. For all practical purposes within the monitoring well installation industry, grout refers to the solidified material which is installed and occupies the annular space above the bentonite pellet seal. Grout, most of the time, is made up of one or two assemblages of material, (e.g., cement and/or bentonite). A cement-bentonite grout, which is the most common type of grout used in monitoring well completions, normally is a mixture of cement, bentonite, and water at a ratio of one 90-pound bag of Portland Type I cement, plus 3 to 5 pounds of granular or flake-type bentonite, and 6-7 gallons of water. A neat cement consists of one ninety-pound bag of Portland Type I cement and 6-7 gallons of water. A bentonite slurry (bentonite and water mixed to a thick but pumpable mixture) is sometimes used instead of grout for deep well installations where placement of bentonite pellets is difficult. Bentonite chips are also occasionally used for annular backfill in place of grout.

In certain cases, the borehole may be drilled to a depth greater than the anticipated well installation depth. For these cases, the well shall be backfilled to the desired depth with bentonite pellets/chips or cement grout. A short (1- to 2-foot) section of capped riser pipe sump is sometimes installed immediately below the screen, as a silt reservoir, when significant post-development silt is anticipated. This will ensure that the entire screen surface remains unobstructed.

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5.2.4 Protective Casing

When the well is completed and grouted to the surface, a protective steel casing is typically placed over the top of the well. This casing generally has a hinged cap and can be locked to prevent vandalism. The protective casing has a larger diameter than the well and is set into the wet cement grout over the well upon completion. In addition, one hole is drilled just above the cement collar through the protective casing which acts as a weep hole for the flow of water which may enter the annulus during well development, purging, or sampling.

A protective casing which is level with the ground surface (flush-mounted) is used in roadway or parking lot applications where the top of a monitoring well must be below the pavement. The top of the riser pipe is placed 4 to 5 inches below the pavement, and a locking protective casing is cemented in place to 3 inches below the pavement. A large diameter, manhole-type protective collar is set into the wet cement around the well with the top set level with or slightly above the pavement. An appropriately-sized id is placed over the protective sleeve. The cement should be slightly mounded to direct pooled water away from the well head.

5.3 Monitoring Well Installation

Pertinent data regarding monitoring well installation shall be recorded on log sheets as depicted and discussed in SOP SA-6.3. Attachments to this referenced SOP illustrate terms and physical construction of various types of monitoring wells.

5.3.1 Monitoring Wells in Unconsolidated Sediments

After the borehole is drilled to the desired depth, well installation can begin. The procedure for well installation will partially be dictated by the stability of the formation in which the well is being placed. If the borehole collapses immediately after the drilling tools are withdrawn, then a temporary casing must be installed and well installation will proceed through the center of the temporary casing, and continue as the temporary casing is withdrawn from the borehole. In the case of hollow-stem auger drilling, the augers will act to stabilize the borehole during well installation.

Before the screen and riser pipe are lowered into the borehole, all pipe and screen sections should be measured with an engineer's rule to ensure proper placement. When measuring sections, the threads on one end of the pipe or screen must be excluded while measuring, since the pipe and screen sections are screwed flush together.

After the screen and riser pipe are lowered through the temporary casing, the sand pack can be installed. A weighted tape measure must be used during the installation procedure to carefully monitor installation progress. The sand is slowly poured into the annulus between the riser pipe and temporary casing, as the casing is withdrawn. Sand should always be kept within the temporary casing during withdrawal in order to ensure an adequate sand pack. However, if too much sand is within the temporary casing (greater than 1 foot above the bottom of the casing) bridging between the temporary casing and riser pipe may occur. Centralizers may be used at the geologist's discretion, one above and one below the screen, to assure enough annular space for sand pack placement.

After the sand pack is installed to the desired depth (at least 1 foot above the top of the screen), then the bentonite pellet seal (or equivalent), can be installed in the same manner as the sand pack. At least 1 to 3 feet of bentonite pellets should be installed above the sand pack. Pellets should be added slowly and their fall monitored closely to ensure that bridging does not occur.

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The cement-bentonite grout is then mixed and tremied into the annulus as the temporary casing or augers are withdrawn. Finally, the protective casing can be installed as detailed in Section 5.2.4.

5.3.2 Confining Layer Monitoring Wells

When drilling and installing a well in a confined aquifer, proper well installation techniques must be applied to avoid cross contamination between aquifers. Under most conditions, this can be accomplished by installing double-cased wells. This is accomplished by drilling a large-diameter boring through the upper aquifer, 1 to 5 feet into the underlying confining layer, and setting and pressure grouting or tremie grouting a large-diameter casing into the confining layer. The grout material must fill the space between the native material and the outer casing. A smaller diameter boring is then continued through the confining layer for installation of the monitoring well as detailed for overburden monitoring wells. Sufficient time (determined by the field geologist), must be allowed for setting of the grout prior to drilling through the confined layer.

5.3.3 Bedrock Monitoring Wells

When installing bedrock monitoring wells, a large diameter boring is drilled through the overburden and approximately 5-10 feet into bedrock. A casing (typically steel) is installed and either pressure grouted or tremie grouted in place. After the grout has cured, a smaller diameter boring is continued into bedrock to the desired depth. If the boring does not collapse, the well can be left open, and a screen is not necessary. If the boring collapses, then a screen is required and can be installed as detailed for overburden monitoring wells. If a screen is to be used, then the casing which is installed through the overburden and into the bedrock does not require grouting and can be removed when the final well installation is completed.

5.3.4 Drive Points

Drive points can be installed with either a sledge hammer, drop hammer, or a mechanical vibrator. The screen section is threaded and tightened onto the riser pipe with pipe wrenches. The drive point is simply pounded into the subsurface to the desired depth. If a heavy drop hammer is used, then a tripod and pulley setup is required to lift the hammer. Drive points typically cannot be manually driven to depths exceeding 10 feet.

Direct push sampling/monitoring point installation methods, using a direct push rig or drilling rig, are described in SOP SA-2.5.

5.3.5 Innovative Monitoring Well Installation Techniques

Certain innovative sampling devices have proven advantageous. These devices are essentially screened samplers installed in a borehole with only small-diameter tubes extending to the surface. This reduces drilling costs, decreases the volume of stagnant water, and provides a sampling system that minimizes cross-contamination from sampling equipment. Four manufacturers of these samplers include Timco Manufacturing Company, Inc., of Prairie du Sac, Wisconsin, BARCAD Systems, Inc., of Concord, Massachusetts, Westbay Instruments Ltd. of Vancouver, British Columbia, Canada and the University of Waterloo at Waterloo, Ontario, Canada. Each manufacturer offers various construction materials.

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5.4 Well Development Methods

The purpose of well development is to stabilize and increase the permeability of the gravel pack around the well screen, and to restore the permeability of the formation which may have been reduced by drilling operations. Wells are typically developed until all fine material and drilling water is removed from the well. Sequential measurements of pH, conductivity and temperature taken during development may yield information (stabilized values) regarding whether sufficient development has been performed. The selection of the well development method shall be made by the field geologist and is based on the drilling methods, well construction and installation details, and the characteristics of the formation that the well is screened in. The primary methods of well development are summarized below. A more detailed discussion may be found in Driscoll (1986).

5.4.1 Overpumping and Backwashing

Wells may be developed by alternatively drawing the water level down at a high rate (by pumping or bailing) and then reversing the flow direction (backwashing) so that water is passing from the well into the formation. This back and forth movement of water through the well screen and gravel pack serves to remove fines from the formation immediately adjacent to the well, while preventing bridging (wedging) of sand grains. Backwashing can be accomplished by several methods, including pouring water into the well and then bailing, starting and stopping a pump intermittently to change water levels, or forcing water into the well under pressure through a water-tight fitting ("rawhiding"). Care should be taken when backwashing not to apply too much pressure, which could damage or destroy the well screen.

5.4.2 Surging with a Surge Plunger

A surge plunger (also called a surge block) is approximately the same diameter as the well casing and is aggressively moved up and down within the well to agitate the water, causing it to move in and out of the screens. This movement of water pulls fine materials into the well, where they may be removed by any of several methods, and prevents bridging of sand particles in the gravel pack. There are two basic types of surge plungers; solid and valved surge plungers. In formations with low yields, a valved surge plunger may be preferred, as solid plungers tend to force water out of the well at a greater rate than it will flow back in. Valved plungers are designed to produce a greater inflow than outflow of water during surging.

5.4.3 Compressed Air

Compressed air can be used to develop a well by either of two methods: backwashing or surging. Backwashing is done by forcing water out through the screens, using increasing air pressure inside a sealed well, then releasing the pressurized air to allow the water to flow back into the well. Care should be taken when using this method so that the water level does not drop below the top of the screen, thus introducing air into the formation and reducing well yield. Surging, or the "open well" method, consists of alternately releasing large volumes of air suddenly into an open well below the water level to produce a strong surge by virtue of the resistance of water head, friction, and inertia. Pumping of the well is subsequently done using the air lift method.

5.4.4 High Velocity Jetting

In the high velocity jetting method, water is forced at high velocities from a plunger-type device and through the well screen to loosen fine particles from the sand pack and surrounding formation. The jetting tool is slowly rotated and raised and lowered along the length of the well screen to develop the entire

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screened area. Jetting using a hose lowered into the well may also be effective. The fines washed into the screen during this process can then be bailed or pumped from the well.

6.0 RECORDS

A critical part of monitoring well installation is recording of all significant details and events in the site logbook or field notebook. The geologist must record the exact depths of significant hydrogeological features, screen placement, gravel pack placement, and bentonite placement.

A Monitoring Well Sheet (see Attachments to SOP SA-6.3) shall be completed, ensuring the uniform recording of data for each installation and rapid identification of missing information. Well depth, length, materials of construction, length and openings of screen, length and type of riser, and depth and type of all backfill materials shall be recorded. Additional information shall include location, installation date, problems encountered, water levels before and after well installation, cross-reference to the geologic boring log, and methods used during the installation and development process. Documentation is very important to prevent problems involving questionable sample validity. Somewhat different information will need to be recorded, depending on whether the well is completed in overburden (single- or double-cased), as a cased well in bedrock, or as an open hole in bedrock.

The quantities of sand, bentonite, and grout placed in the well are also important. The geologist shall calculate the annular space volume and have an idea of the quantity of material needed to fill the annular space. Volumes of backfill significantly higher than the calculated volume may indicate a problem such as a large cavity, while a smaller backfill volume may indicate a cave-in or bridging of the backfill materials. Any problems with rig operation or down-time shall be recorded and may affect the driller's final fee.

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ATTACHMENT A

RELATIVE COMPATIBILITY OF RIGID WELL CASING MATERIAL (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material						
	PVC 1	Galvanized Steel	Carbon Steel	Lo-carbon Steel	Stainless Steel 304	Stainless Steel 316	Teflon*
Buffered Weak Acid	100	56	51	59	97	100	100
Weak Acid	98	59	43	47	96	100	100
Mineral Acid/ High Solids Content	100	48	57	60	80	82	100
Aqueous/Organic Mixtures	64	69	73	73	98	100	100
Percent Overall Rating	91	58	56	59	93	96	100

Preliminary Ranking of Rigid Materials:

- | | | | |
|----|---------------------|---|------------------|
| 1 | Teflon* | 5 | Lo-Carbon Steel |
| 2 | Stainless Steel 316 | 6 | Galvanized Steel |
| 3. | Stainless Steel 304 | 7 | Carbon Steel |
| 4 | PVC 1 | | |

* Trademark of DuPont

RELATIVE COMPATIBILITY OF SEMI-RIGID OR ELASTOMERIC MATERIALS (PERCENT)

Potentially-Deteriorating Substance	Type of Casing Material								
	PVC Flexible	PP	PE Conv.	PE Linear	PMM	Viton*	Silicone	Neoprene	Teflon**
Buffered Weak Acid	97	97	100	97	90	92	87	85	100
Weak Acid	92	90	94	96	78	78	75	75	100
Mineral Acid/ High Solids Content	100	100	100	100	95	100	78	82	100
Aqueous/Organic Mixtures	62	71	40	60	49	78	49	44	100
Percent Overall Rating	88	90	84	88	78	87	72	72	100

Preliminary Ranking of Semi-Rigid or Elastomeric Materials:

- | | | | |
|----|------------------------|---|------------------------|
| 1 | Teflon* | 5 | PE Conventional |
| 2 | Polypropylene (PP) | 6 | Plexiglas/Lucite (PMM) |
| 3. | PVC Flexible/PE Linear | 7 | Silicone/Neoprene |
| 4 | Viton* | | |

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Source: Barcelona et al., 1983

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ATTACHMENT B

COMPARISON OF STAINLESS STEEL AND PVC FOR MONITORING WELL CONSTRUCTION

Characteristic	Stainless Steel	PVC
Strength	Use in deep wells to prevent compression and closing of screen/riser.	Use when shear and compressive strength are not critical.
Weight	Relatively heavier.	Light-weight; floats in water.
Cost	Relatively expensive.	Relatively inexpensive.
Corrosivity	Deteriorates more rapidly in corrosive water.	Non-corrosive -- may deteriorate in presence of ketones, aromatics, alkyl sulfides, or some chlorinated hydrocarbons.
Ease of Use	Difficult to adjust size or length in the field.	Easy to handle and work with in the field.
Preparation for Use	Should be steam cleaned if organics will be subsequently sampled.	Never use glue fittings -- pipes should be threaded or pressure fitted. Should be steam cleaned when used for monitoring wells.
Interaction with Contaminants*	May sorb organic or inorganic substances when oxidized.	May sorb or release organic substances.

* See also Attachment A.



TETRA TECH NUS, INC.

STANDARD OPERATING PROCEDURES

Subject
BOREHOLE AND SAMPLE LOGGING

Number	GH-1.5	Page	1 of 20
Effective Date	06/99	Revision	1
Applicability	Tetra Tech NUS, Inc.		
Prepared	Earth Sciences Department		
Approved	D. Senovich		

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1.0 PURPOSE

The purpose of this document is to establish standard procedures and technical guidance on borehole and sample logging.

2.0 SCOPE

These procedures provide descriptions of the standard techniques for borehole and sample logging. These techniques shall be used for each boring logged to provide consistent descriptions of subsurface lithology. While experience is the only method to develop confidence and accuracy in the description of soil and rock, the field geologist/engineer can do a good job of classification by careful, thoughtful observation and by being consistent throughout the classification procedure.

3.0 GLOSSARY

None.

4.0 RESPONSIBILITIES

Site Geologist. Responsible for supervising all boring activities and assuring that each borehole is completely logged. If more than one rig is being used on site, the Site Geologist must make sure that each field geologist is properly trained in logging procedures. A brief review or training session may be necessary prior to the start up of the field program and/or upon completion of the first boring.

5.0 PROCEDURES

The classification of soil and rocks is one of the most important jobs of the field geologist/engineer. To maintain a consistent flow of information, it is imperative that the field geologist/engineer understand and accurately use the field classification system described in this SOP. This identification is based on visual examination and manual tests.

5.1 Materials Needed

When logging soil and rock samples, the geologist or engineer may be equipped with the following:

- Rock hammer
- Knife
- Camera
- Dilute hydrochloric acid (HCl)
- Ruler (marked in tenths and hundredths of feet)
- Hand Lens

5.2 Classification of Soils

All data shall be written directly on the boring log (Figure 1) or in a field notebook if more space is needed. Details on filling out the boring log are discussed in Section 5.5.

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5.2.1 USCS Classification

Soils are to be classified according to the Unified Soil Classification System (USCS). This method of classification is detailed in Figure 1 (Continued).
This method of classification identifies soil types on the basis of grain size and cohesiveness.

Fine-grained soils, or fines, are smaller than the No. 200 sieve and are of two types: silt (M) and clay (C). Some classification systems define size ranges for these soil particles, but for field classification purposes, they are identified by their respective behaviors. Organic material (O) is a common component of soil but has no size range; it is recognized by its composition. The careful study of the USCS will aid in developing the competence and consistency necessary for the classification of soils.

Coarse-grained soils shall be divided into rock fragments, sand, or gravel. The terms sand and gravel not only refer to the size of the soil particles but also to their depositional history. To insure accuracy in description, the term rock fragments shall be used to indicate angular granular materials resulting from the breakup of rock. The sharp edges typically observed indicate little or no transport from their source area, and therefore the term provides additional information in reconstructing the depositional environment of the soils encountered. When the term "rock fragments" is used it shall be followed by a size designation such as "(1/4 inch Φ -1/2 inch Φ)" or "coarse-sand size" either immediately after the entry or in the remarks column. The USCS classification would not be affected by this variation in terms.

5.2.2 Color

Soil colors shall be described utilizing a single color descriptor preceded, when necessary, by a modifier to denote variations in shade or color mixtures. A soil could therefore be referred to as "gray" or "light gray" or "blue-gray." Since color can be utilized in correlating units between sampling locations, it is important for color descriptions to be consistent from one boring to another.

Colors must be described while the sample is still moist. Soil samples shall be broken or split vertically to describe colors. Samplers tend to smear the sample surface creating color variations between the sample interior and exterior.

The term "mottled" shall be used to indicate soils irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration and lack of good drainage.

Soil Color Charts shall not be used unless specified by the project manager.

5.2.3 Relative Density and Consistency

To classify the relative density and/or consistency of a soil, the geologist is to first identify the soil type. Granular soils contain predominantly sands and gravels. They are noncohesive (particles do not adhere well when compressed). Finer-grained soils (silts and clays) are cohesive (particles will adhere together when compressed).

The density of noncohesive, granular soils is classified according to standard penetration resistances obtained from split-barrel sampling performed according to the methods detailed in Standard Operating Procedures GH-1.3 and SA-1.3. Those designations are:

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Designation	Standard Penetration Resistance (Blows per Foot)
Very loose	0 to 4
Loose	5 to 10
Medium dense	11 to 30
Dense	31 to 50
Very dense	Over 50

Standard penetration resistance is the number of blows required to drive a split-barrel sampler with a 2-inch outside diameter 12 inches into the material using a 140-pound hammer falling freely through 30 inches. The sampler is driven through an 18-inch sample interval, and the number of blows is recorded for each 6-inch increment. The density designation of granular soils is obtained by adding the number of blows required to penetrate the last 12 inches of each sample interval. It is important to note that if gravel or rock fragments are broken by the sampler or if rock fragments are lodged in the tip, the resulting blow count will be erroneously high, reflecting a higher density than actually exists. This shall be noted on the log and referenced to the sample number. Granular soils are given the USCS classifications GW, GP, GM, SW, SP, SM, GC, or SC (see Figure 1).

The consistency of cohesive soils is determined by performing field tests and identifying the consistency as shown in Figure 2.

Cohesive soils are given the USCS classifications ML, MH, CL, CH, OL, or OH (see Figure 1).

The consistency of cohesive soils is determined either by blow counts, a pocket penetrometer (values listed in the table as Unconfined Compressive Strength), or by hand by determining the resistance to penetration by the thumb. The pocket penetrometer and thumb determination methods are conducted on a selected sample of the soil, preferably the lowest 0.5 foot of the sample in the split-barrel sampler. The sample shall be broken in half and the thumb or penetrometer pushed into the end of the sample to determine the consistency. Do not determine consistency by attempting to penetrate a rock fragment. If the sample is decomposed rock, it is classified as a soft decomposed rock rather than a hard soil. Consistency shall not be determined solely by blow counts. One of the other methods shall be used in conjunction with it. The designations used to describe the consistency of cohesive soils are shown in Figure 2.

5.2.4 Weight Percentages

In nature, soils are comprised of particles of varying size and shape, and are combinations of the various grain types. The following terms are useful in the description of soil:

Terms of Identifying Proportion of the Component	Defining Range of Percentages by Weight
Trace	0 - 10 percent
Some	11 - 30 percent
Adjective form of the soil type (e.g., "sandy")	31 - 50 percent

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FIGURE 2

CONSISTENCY FOR COHESIVE SOILS

Consistency	Standard Penetration Resistance (Blows per Foot)	Unconfined Compressive Strength (Tons/Sq. Foot by pocket penetration)	Field Identification
Very soft	0 to 2	Less than 0.25	Easily penetrated several inches by fist
Soft	2 to 4	0.25 to 0.50	Easily penetrated several inches by thumb
Medium stiff	4 to 8	0.50 to 1.0	Can be penetrated several inches by thumb with moderate effort
Stiff	8 to 15	1.0 to 2.0	Readily indented by thumb but penetrated only with great effort
Very stiff	15 to 30	2.0 to 4.0	Readily indented by thumbnail
Hard	Over 30	More than 4.0	Indented with difficulty by thumbnail

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Examples:

- Silty fine sand: 50 to 69 percent fine sand, 31 to 50 percent silt.
- Medium to coarse sand, some silt: 70 to 80 percent medium to coarse sand, 11 to 30 percent silt.
- Fine sandy silt, trace clay: 50 to 68 percent silt, 31 to 49 percent fine sand, 1 to 10 percent clay.
- Clayey silt, some coarse sand: 70 to 89 percent clayey silt, 11 to 30 percent coarse sand.

5.2.5 Moisture

Moisture content is estimated in the field according to four categories: dry, moist, wet, and saturated. In dry soil, there appears to be little or no water. Saturated samples obviously have all the water they can hold. Moist and wet classifications are somewhat subjective and often are determined by the individual's judgment. A suggested parameter for this would be calling a soil wet if rolling it in the hand or on a porous surface liberates water, i.e., dirties or muddies the surface. Whatever method is adopted for describing moisture, it is important that the method used by an individual remains consistent throughout an entire drilling job.

Laboratory tests for water content shall be performed if the natural water content is important.

5.2.6 Stratification

Stratification can only be determined after the sample barrel is opened. The stratification or bedding thickness for soil and rock is depending on grain size and composition. The classification to be used for stratification description is shown in Figure 3.

5.2.7 Texture/Fabric/Bedding

The texture/fabric/bedding of the soil shall be described. Texture is described as the relative angularity of the particles: rounded, subrounded, subangular, and angular. Fabric shall be noted as to whether the particles are flat or bulky and whether there is a particular relation between particles (i.e., all the flat particles are parallel or there is some cementation). The bedding or structure shall also be noted (e.g., stratified, lensed, nonstratified, heterogeneous varved).

5.2.8 Summary of Soil Classification

In summary, soils shall be classified in a similar manner by each geologist/engineer at a project site. The hierarchy of classification is as follows:

- Density and/or consistency
- Color
- Plasticity (Optional)
- Soil types
- Moisture content
- Stratification
- Texture, fabric, bedding
- Other distinguishing features

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FIGURE 3

BEDDING THICKNESS CLASSIFICATION

Thickness (metric)	Thickness (Approximate English Equivalent)	Classification
> 1.0 meter	> 3.3'	Massive
30 cm - 1 meter	1.0' - 3.3'	Thick Bedded
10 cm - 30 cm	4" - 1.0'	Medium Bedded
3 cm - 10 cm	1" - 4"	Thin Bedded
1 cm - 3 cm	2/5" - 1"	Very Thin Bedded
3 mm - 1 cm	1/8" - 2/5"	Laminated
1 mm - 3 mm	1/32" - 1/8"	Thinly Laminated
< 1 mm	< 1/32"	Micro Laminated

(Weir, 1973 and Ingram, 1954)

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5.3 Classification of Rocks

Rocks are grouped into three main divisions: sedimentary, igneous and metamorphic. Sedimentary rocks are by far the predominant type exposed at the earth's surface. The following basic names are applied to the types of rocks found in sedimentary sequences:

- Sandstone - Made up predominantly of granular materials ranging between 1/16 to 2 mm in diameter.
- Siltstone - Made up of granular materials less than 1/16 to 1/256 mm in diameter. Fractures irregularly. Medium thick to thick bedded.
- Claystone - Very fine-grained rock made up of clay and silt-size materials. Fractures irregularly. Very smooth to touch. Generally has irregularly spaced pitting on surface of drilled cores.
- Shale - A fissile very fine-grained rock. Fractures along bedding planes.
- Limestone - Rock made up predominantly of calcite (CaCO_3). Effervesces strongly upon the application of dilute hydrochloric acid.
- Coal - Rock consisting mainly of organic remains.
- Others - Numerous other sedimentary rock types are present in lesser amounts in the stratigraphic record. The local abundance of any of these rock types is dependent upon the depositional history of the area. Conglomerate, halite, gypsum, dolomite, anhydrite, lignite, etc. are some of the rock types found in lesser amounts.

In classifying a sedimentary rock the following hierarchy shall be noted:

- Rock type
- Color
- Bedding thickness
- Hardness
- Fracturing
- Weathering
- Other characteristics

5.3.1 Rock Type

As described above, there are numerous types of sedimentary rocks. In most cases, a rock will be a combination of several grain types, therefore, a modifier such as a sandy siltstone, or a silty sandstone can be used. The modifier indicates that a significant portion of the rock type is composed of the modifier. Other modifiers can include carbonaceous, calcareous, siliceous, etc.

Grain size is the basis for the classification of clastic sedimentary rocks. Figure 4 is the Udden-Wentworth classification that will be assigned to sedimentary rocks. The individual boundaries are slightly different than the USCS subdivision for soil classification. For field determination of grain sizes, a scale can be used for the coarse grained rocks. For example, the division between siltstone and claystone may not be measurable in the field. The boundary shall be determined by use of a hand lens. If the grains cannot be seen with the naked eye but are distinguishable with a hand lens, the rock is a siltstone. If the grains are not distinguishable with a hand lens, the rock is a claystone.

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FIGURE 4

GRAIN SIZE CLASSIFICATION FOR ROCKS

Particle Name	Grain Size Diameter
Cobbles	> 64 mm
Pebbles	4 - 64 mm
Granules	2 - 4 mm
Very Coarse Sand	1 - 2 mm
Coarse Sand	0.5 - 1 mm
Medium Sand	0.25 - 0.5 mm
Fine Sand	0.125 - 0.25 mm
Very Fine Sand	0.0625 - 0.125 mm
Silt	0.0039 - 0.0625 mm

After Wentworth, 1922

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5.3.2 Color

The color of a rock can be determined in a similar manner as for soil samples. Rock core samples shall be classified while wet, when possible, and air cored samples shall be scraped clean of cuttings prior to color classifications.

Rock color charts shall not be used unless specified by the Project Manager.

5.3.3 Bedding Thickness

The bedding thickness designations applied to soil classification (see Figure 3) will also be used for rock classification.

5.3.4 Hardness

The hardness of a rock is a function of the compaction, cementation, and mineralogical composition of the rock. A relative scale for sedimentary rock hardness is as follows:

- Soft - Weathered, considerable erosion of core, easily gouged by screwdriver, scratched by fingernail. Soft rock crushes or deforms under pressure of a pressed hammer. This term is always used for the hardness of the saprolite (decomposed rock which occupies the zone between the lowest soil horizon and firm bedrock).
- Medium soft - Slight erosion of core, slightly gouged by screwdriver, or breaks with crumbly edges from single hammer blow.
- Medium hard - No core erosion, easily scratched by screwdriver, or breaks with sharp edges from single hammer blow.
- Hard - Requires several hammer blows to break and has sharp conchoidal breaks. Cannot be scratched with screwdriver.

Note the difference in usage here of the words "scratch" and "gouge." A scratch shall be considered a slight depression in the rock (do not mistake the scraping off of rock flour from drilling with a scratch in the rock itself), while a gouge is much deeper.

5.3.5 Fracturing

The degree of fracturing or brokenness of a rock is described by measuring the fractures or joint spacing. After eliminating drilling breaks, the average spacing is calculated and the fracturing is described by the following terms:

- Very broken (V. BR.) - Less than 2-inch spacing between fractures
- Broken (BR.) - 2-inch to 1-foot spacing between fractures
- Blocky (BL.) - 1- to 3-foot spacing between fractures
- Massive (M.) - 3 to 10-foot spacing between fractures

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The structural integrity of the rock can be approximated by calculating the Rock Quality Designation (RQD) of cores recovered. The RQD is determined by adding the total lengths of all pieces exceeding 4 inches and dividing by the total length of the coring run, to obtain a percentage.

Method of Calculating RQD
(After Deere, 1964)

$$RQD \% = r/l \times 100$$

r = Total length of all pieces of the lithologic unit being measured, which are greater than 4 inches length, and have resulted from natural breaks. Natural breaks include slickensides, joints, compaction slicks, bedding plane partings (not caused by drilling), friable zones, etc.

l = Total length of the coring run.

5.3.6 Weathering

The degree of weathering is a significant parameter that is important in determining weathering profiles and is also useful in engineering designs. The following terms can be applied to distinguish the degree of weathering:

- Fresh - Rock shows little or no weathering effect. Fractures or joints have little or no staining and rock has a bright appearance.
- Slight - Rock has some staining which may penetrate several centimeters into the rock. Clay filling of joints may occur. Feldspar grains may show some alteration.
- Moderate - Most of the rock, with exception of quartz grains, is stained. Rock is weakened due to weathering and can be easily broken with hammer.
- Severe - All rock including quartz grains is stained. Some of the rock is weathered to the extent of becoming a soil. Rock is very weak.

5.3.7 Other Characteristics

The following items shall be included in the rock description:

- Description of contact between two rock units. These can be sharp or gradational.
- Stratification (parallel, cross stratified).
- Description of any filled cavities or vugs.
- Cementation (calcareous, siliceous, hematitic).
- Description of any joints or open fractures.
- Observation of the presence of fossils.
- Notation of joints with depth, approximate angle to horizontal, any mineral filling or coating, and degree of weathering.

All information shown on the boring logs shall be neat to the point where it can be reproduced on a copy machine for report presentation. The data shall be kept current to provide control of the drilling program and to indicate various areas requiring special consideration and sampling.

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5.3.8 Additional Terms Used In the Description of Rock

The following terms are used to further identify rocks:

- Seam - Thin (12 inches or less), probably continuous layer.
- Some - Indicates significant (15 to 40 percent) amounts of the accessory material. For example, rock composed of seams of sandstone (70 percent) and shale (30 percent) would be "sandstone -- some shale seams."
- Few - Indicates insignificant (0 to 15 percent) amounts of the accessory material. For example, rock composed of seam of sandstone (90 percent) and shale (10 percent) would be "sandstone -- few shale seams."
- Interbedded - Used to indicate thin or very thin alternating seams of material occurring in approximately equal amounts. For example, rock composed of thin alternating seams of sandstone (50 percent) and shale (50 percent) would be "interbedded sandstone and shale."
- Interlayered - Used to indicate thick alternating seams of material occurring in approximately equal amounts.

The preceding sections describe the classification of sedimentary rocks. The following are some basic names that are applied to igneous rocks:

- Basalt - A fine-grained extrusive rock composed primarily of calcic plagioclase and pyroxene.
- Rhyolite - A fine-grained volcanic rock containing abundant quartz and orthoclase. The fine-grained equivalent of a granite.
- Granite - A coarse-grained plutonic rock consisting essentially of alkali feldspar and quartz.
- Diorite - A coarse-grained plutonic rock consisting essentially of sodic plagioclase and hornblende.
- Gabbro - A coarse-grained plutonic rock consisting of calcic plagioclase and clinopyroxene. Loosely used for any coarse-grained dark igneous rock.

The following are some basic names that are applied to metamorphic rocks:

- Slate - A very fine-grained foliated rock possessing a well developed slaty cleavage. Contains predominantly chlorite, mica, quartz, and sericite.
- Phyllite - A fine-grained foliated rock that splits into thin flaky sheets with a silky sheen on cleavage surface.
- Schist - A medium to coarse-grained foliated rock with subparallel arrangement of the micaceous minerals which dominate its composition.
- Gneiss - A coarse-grained foliated rock with bands rich in granular and platy minerals.
- Quartzite - A fine- to coarse-grained nonfoliated rock breaking across grains, consisting essentially of quartz sand with silica cement.

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5.4 Abbreviations

Abbreviations may be used in the description of a rock or soil. However, they shall be kept at a minimum. Following are some of the abbreviations that may be used:

C - Coarse	Lt - Light	Yl - Yellow
Med - Medium	BR - Broken	Or - Orange
F - Fine	BL - Blocky	SS - Sandstone
V - Very	M - Massive	Sh - Shale
Sl - Slight	Br - Brown	LS - Limestone
Occ - Occasional	Bl - Black	Fgr - Fine-grained
Tr - Trace		

5.5 Boring Logs and Documentation

This section describes in more detail the procedures to be used in completing boring logs in the field. Information obtained from the preceding sections shall be used to complete the logs. A sample boring log has been provided as Figure 5.

The field geologist/engineer shall use this example as a guide in completing each boring log. Each boring log shall be fully described by the geologist/engineer as the boring is being drilled. Every sheet contains space for 25 feet of log. Information regarding classification details is provided either on the back of the boring log or on a separate sheet, for field use.

5.5.1 Soil Classification

- Identify site name, boring number, job number, etc. Elevations and water level data to be entered when surveyed data is available.
- Enter sample number (from SPT) under appropriate column. Enter depth sample was taken from (1 block = 1 foot). Fractional footages, i.e., change of lithology at 13.7 feet, shall be lined off at the proportional location between the 13- and 14-foot marks. Enter blow counts (Standard Penetration Resistance) diagonally (as shown). Standard penetration resistance is covered in Section 5.2.3.
- Determine sample recovery/sample length as shown. Measure the total length of sample recovered from the split-spoon sampler, including material in the drive shoe. Do not include cuttings or wash material that may be in the upper portion of the sample tube.
- Indicate any change in lithology by drawing a line at the appropriate depth. For example, if clayey silt was encountered from 0 to 6.5 feet and shale from 6.5 to 6.0 feet, a line shall be drawn at this increment. This information is helpful in the construction of cross-sections. As an alternative, symbols may be used to identify each change in lithology.
- The density of granular soils is obtained by adding the number of blows for the last two increments. Refer to Density of Granular Soils Chart on back of log sheet. For consistency of cohesive soils refer also to the back of log sheet - Consistency of Cohesive Soils. Enter this information under the appropriate column. Refer to Section 5.2.3.

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FIGURE 5
COMPLETED BORING LOG (EXAMPLE)



BORING LOG

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PROJECT NAME: NSB-SITE BORING NUMBER: SB/MW1
 PROJECT NUMBER: 9594 DATE: 3/8/96
 DRILLING COMPANY: SOILTEST CO. GEOLOGIST: SJ CONTI
 DRILLING RIG: CME-85 DRILLER: R. ROCK

Sample No. and Type or ROD	Depth (ft) or Run No.	Blows / 1" or SPT (ft)	Sample Recovery Sample Length	Lithology Change (Depth/ft) or Corrosion Interval	Soil Density/Consistency or Rock Hardness	Color	Material Classification	U S C S	Remarks	PIVOT Reading (ppm)			
										Sample	Sampler B2	Sampler B1	Driller B1
S-1 0800	0.0 2.0	7 10	1.5 2.0		M DENSE	BN TO BLK	SILTY SAND - SOME ROCK FR. - TR BAKES (FILL)	SM	MOIST SL. ORG. ODR FILL TO 4'±	5	0	0	0
S-2 0810	4.0 6.0	5 9	2.0 3.0	4.0	M DENSE	BN	SILTY SAND - TR FINE GRAVEL	SM	MOIST - W ODR NAT. MATL. TOOK SAMPLE SB01-0406 FOR ANALYSIS	10	0	1	1
S-3 0820	8.0 10.0	6 12	1.5 2.0	8.0	DENSE	TAN GRN	FINE TO COARSE SAND TR.F. GRAVEL	SW	WET HIT WATER: 7'±	0	0	0	0
S-4 0830	12.0 14.0	7 13	1.5 2.0	12.0	STIFF	GRN	SILTY CLAY	CL	MOIST - WET	0	3	1	1
S-5 0840	16.0 18.0	10 16	2.0 3.0	16.0	M HARD	BN	SILTSTONE	NE	WEATHERED LO 2 JNTS @ 15.5 WATER SPACES @ 16.5, 17.5 LOSING SOME	0	0	0	0
S-6 0850	20.0 22.0	15 21	2.5 3.0	20.0	HARD	GRY	SANDSTONE - SOME SILTSTONE	BR	DRILL H2O @ 17'± SET TEMP 6" CAS TO 15.5	0	0	0	0
S-7 0900	24.0 26.0	20 26	2.5 3.0	24.0					SAND M-25 PEBBLES 12-14	0	0	0	0

* When each casing, enter each between.
 ** Include monitor reading in 0 foot intervals @ benchlogs. Increase reading frequency if elevated response read.
 Remarks: CME-85 RIG, 4 1/4" ID HSA - 9" OOD
2" SPLIT SPANNER - 160 LB HAMMER - 30" DROP
ANY COLE IN BEDROCK RUN @ 25 min. RUN (3) IS MIN
 Converted to Well Yes ☒ No ☐ Well I.D. # MW-1
 Drilling Area 1-208 Background (ppm): 0
1-803

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- Enter color of the material in the appropriate column.
- Describe material using the USCS. Limit this column for sample description only. The predominant material is described last. If the primary soil is silt but has fines (clay) - use clayey silt. Limit soil descriptors to the following:
 - Trace: 0 - 10 percent
 - Some: 11 - 30 percent
 - And/Or: 31 - 50 percent
- Also indicate under Material Classification if the material is fill or natural soils. Indicate roots, organic material, etc.
- Enter USCS symbol - use chart on back of boring log as a guide. If the soils fall into one of two basic groups, a borderline symbol may be used with the two symbols separated by a slash. For example ML/CL or SM/SP.
- The following information shall be entered under the "Remarks" column and shall include, but is not limited by, the following:
 - Moisture - estimate moisture content using the following terms - dry, moist, wet and saturated. These terms are determined by the individual. Whatever method is used to determine moisture, be consistent throughout the log.
 - Angularity - describe angularity of coarse grained particles using the terms angular, subangular, subrounded, or rounded. Refer to ASTM D 2488 or Earth Manual for criteria for these terms.
 - Particle shape - flat, elongated, or flat and elongated.
 - Maximum particle size or dimension.
 - Water level observations.
 - Reaction with HCl - none, weak, or strong.
- Additional comments:
 - Indicate presence of mica, caving of hole, when water was encountered, difficulty in drilling, loss or gain of water.
 - Indicate odor and Photolization Detector (PID) or Flame Ionization Detector (FID) reading if applicable.
 - Indicate any change in lithology by drawing a line through the lithology change column and indicate the depth. This will help when cross-sections are subsequently constructed.
 - At the bottom of the page indicate type of rig, drilling method, hammer size and drop, and any other useful information (i.e., borehole size, casing set, changes in drilling method).

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- Vertical lines shall be drawn (as shown in Figure 5) in columns 6 to 8 from the bottom of each sample to the top of the next sample to indicate consistency of material from sample to sample, if the material is consistent. Horizontal lines shall be drawn if there is a change in lithology, then vertical lines drawn to that point.
- Indicate screened interval of well, as needed, in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

5.5.2 Rock Classification

- Indicate depth at which coring began by drawing a line at the appropriate depth. Indicate core run depths by drawing coring run lines (as shown) under the first and fourth columns on the log sheet. Indicate RQD, core run number, RQD percent, and core recovery under the appropriate columns.
- Indicate lithology change by drawing a line at the appropriate depth as explained in Section 5.5.1.
- Rock hardness is entered under designated column using terms as described on the back of the log or as explained earlier in this section.
- Enter color as determined while the core sample is wet; if the sample is cored by air, the core shall be scraped clean prior to describing color.
- Enter rock type based on sedimentary, igneous or metamorphic. For sedimentary rocks use terms as described in Section 5.3. Again, be consistent in classification. Use modifiers and additional terms as needed. For igneous and metamorphic rock types use terms as described in Sections 5.3.8.
- Enter brokenness of rock or degree of fracturing under the appropriate column using symbols VBR, BR, BL, or M as explained in Section 5.3.5 and as noted on the back of the Boring Log.
- The following information shall be entered under the remarks column. Items shall include but are not limited to the following:
 - Indicate depths of joints, fractures and breaks and also approximate to horizontal angle (such as high, low), i.e., 70° angle from horizontal, high angle.
 - Indicate calcareous zones, description of any cavities or vugs.
 - Indicate any loss or gain of drill water.
 - Indicate drop of drill tools or change in color of drill water.
- Remarks at the bottom of Boring Log shall include:
 - Type and size of core obtained.
 - Depth casing was set.
 - Type of rig used.
- As a final check the boring log shall include the following:
 - Vertical lines shall be drawn as explained for soil classification to indicate consistency of bedrock material.
 - If applicable, indicate screened interval in the lithology column. Show top and bottom of screen. Other details of well construction are provided on the well construction forms.

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5.5.3 Classification of Soil and Rock from Drill Cuttings

The previous sections describe procedures for classifying soil and rock samples when cores are obtained. However, some drilling methods (air/mud rotary) may require classification and borehole logging based on identifying drill cuttings removed from the borehole. Such cuttings provide only general information on subsurface lithology. Some procedures that shall be followed when logging cuttings are:

- Obtain cutting samples at approximately 5-foot intervals, sieve the cuttings (if mud rotary drilling) to obtain a cleaner sample, place the sample into a small sample bottle or "zip lock" bag for future reference, and label the jar or bag (i.e. hole number, depth, date, etc.). Cuttings shall be closely examined to determine general lithology.
- Note any change in color of drilling fluid or cuttings, to estimate changes in lithology.
- Note drop or chattering of drilling tools or a change in the rate of drilling, to determine fracture locations or lithologic changes.
- Observe loss or gain of drilling fluids or air (if air rotary methods are used), to identify potential fracture zones.
- Record this and any other useful information onto the boring log as provided in Figure 1.

This logging provides a general description of subsurface lithology and adequate information can be obtained through careful observation of the drilling process. It is recommended that split-barrel and rock core sampling methods be used at selected boring locations during the field investigation to provide detailed information to supplement the less detailed data generated through borings drilled using air/mud rotary methods.

5.6 Review

Upon completion of the borings logs, copies shall be made and reviewed. Items to be reviewed include:

- Checking for consistency of all logs.
- Checking for conformance to the guideline.
- Checking to see that all information is entered in their respective columns and spaces.

6.0 REFERENCES

Unified Soil Classification System (USCS).

ASTM D2486, 1985.

Earth Manual, U.S. Department of the Interior, 1974.

7.0 RECORDS

Originals of the boring logs shall be retained in the project files.



TETRA TECH NUS, INC.

STANDARD OPERATING PROCEDURES

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Effective Date	06/99	Revision	4
Applicability	Tetra Tech NUS, Inc.		
Prepared	Earth Sciences Department		
Approved	D. Senovich		

Subject
GROUNDWATER SAMPLE ACQUISITION AND
ONSITE WATER QUALITY TESTING

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information regarding the sampling of groundwater wells.

2.0 SCOPE

This procedure provides information on proper sampling equipment, onsite water quality testing, and techniques for groundwater sampling. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require modifications to methodology.

3.0 GLOSSARY

Conductivity – Conductivity is a numerical expression of the ability of an aqueous solution to carry an electric current. This ability depends on the presence of ions, their total concentration, mobility, valence, and relative concentrations, and on temperature of measure. Conductivity is highly dependent on temperature and should be reported at a particular temperature, i.e., 20.2 mS/cm at 14C.

Dissolved Oxygen (DO) – DO levels in natural and wastewater depend on the physical, chemical, and biochemical activities in the water sample.

Oxidation-Reduction Potential (ORP) - A measure of the activity ratio of oxidizing and reducing species as determined by the electromotive force developed by a noble metal electrode, immersed in water, as referenced against a standard hydrogen electrode.

pH - The negative logarithm (base 10) of the hydrogen ion activity. The hydrogen ion activity is related to the hydrogen ion concentration, and, in a relatively weak solution, the two are nearly equal. Thus, for all practical purposes, pH is a measure of the hydrogen ion concentration.

pH Paper - Indicator paper that turns different colors depending on the pH of the solution to which it is exposed. Comparison with color standards supplied by the manufacturer will then give an indication of the solution's pH.

Salinity – Salinity is a unitless property of industrial and natural waters. It is the measurement of dissolved salts in a given mass of solution. Note: most field meters determined salinity automatically from conductivity and temperature. The displayed value will be displayed in either parts per thousand (ppt) or % (e.g., 35 ppt will equal 3.5%).

Turbidity – Turbidity in water is caused by suspended matter, such as clay, silt, fine organic and inorganic matter. Turbidity is an expression the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample.

4.0 RESPONSIBILITIES

Project Hydrogeologist - Responsible for selecting and detailing the specific groundwater sampling techniques, onsite water quality testing (type, frequency, and location), and equipment to be used, and providing detailed input in this regard to the project plan documents. The project hydrogeologist is also responsible for properly briefing and overseeing the performance of the site sampling personnel.

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Project Geologist - is primarily responsible for the proper acquisition of the groundwater samples. He/she is also responsible for the actual analyses of onsite water quality samples, as well as instrument calibration, care, and maintenance. When appropriate, such responsibilities may be performed by other qualified personnel (e.g., field technicians).

5.0 PROCEDURES

5.1 General

To be useful and accurate, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of sampling to the time of analysis in order to keep any changes in water quality parameters to a minimum.

Methods for withdrawing samples from completed wells include the use of pumps, compressed air, bailers, and various types of samplers. The primary considerations in obtaining a representative sample of the groundwater are to avoid collection of stagnant (standing) water in the well and to avoid physical or chemical alteration of the water due to sampling techniques. In a non-pumping well, there will be little or no vertical mixing of water in the well pipe or casing, and stratification will occur. The well water in the screened section will mix with the groundwater due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. To safeguard against collecting non-representative stagnant water in a sample, the following approach shall be followed prior to sample acquisition:

1. All monitoring wells shall be purged prior to obtaining a sample. Evacuation of three to five volumes is recommended prior to sampling. In a high-yielding groundwater formation and where there is no stagnant water in the well above the screened section, extensive evacuation prior to sample withdrawal is not as critical.
2. For wells that can be purged dry, the well shall be evacuated and allowed to recover prior to sample acquisition. If the recovery rate is fairly rapid, evacuation of more than one volume of water is required.
3. For high-yielding monitoring wells which cannot be evacuated to dryness, there is no absolute safeguard against contaminating the sample with stagnant water. One of the following techniques shall be used to minimize this possibility:
 - A submersible pump or the intake line of a surface pump or bailer shall be placed just below the water surface when removing the stagnant water and lowered as the water level drops. Three to five volumes of water shall be removed to provide reasonable assurance that all stagnant water has been evacuated. Once this is accomplished, a bailer or other approved device may be used to collect the sample for analysis.
 - The intake line of the sampling pump (or the submersible pump itself) shall be placed near the bottom of the screened section, and approximately one casing volume of water shall be pumped from the well at a low purge rate, equal to the well's recovery rate (low flow sampling).

Stratification of contaminants may exist in the aquifer. Concentration gradients as a result of mixing and dispersion processes, layers of variable permeability, and the presence of separate-phase product (i.e.,

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floating hydrocarbons) may cause stratification. Excessive pumping or improper sampling methods can dilute or increase the contaminant concentrations in the recovered sample compared to what is representative of the integrated water column as it naturally occurs at that point, thus the result is the collection of a non-representative sample.

5.2 Sampling, Monitoring, and Evacuation Equipment

Sample containers shall conform with the guidelines expressed in SOP SA-6.1.

The following equipment shall be on hand when sampling groundwater wells (reference SOPs SA-6.1 and SA-7.1):

- Sample packaging and shipping equipment - Coolers for sample shipping and cooling, chemical preservatives, appropriate sampling containers and filler, ice, labels and chain-of-custody documents.
- Field tools and instrumentation - Multi-parameters water quality meter capable of measuring ORP, pH, temperature, DO, specific conductance, turbidity and salinity or individual meters (as applicable), pH paper, camera and film (if appropriate), appropriate keys (for locked wells), engineer's rule, water level indicator.
- Pumps
 - Shallow-well pumps: Centrifugal, bladder, suction, or peristaltic pumps with droplines, air-lift apparatus (compressor and tubing) where applicable.
 - Deep-well pumps: Submersible pump and electrical power-generating unit, or bladder pumps where applicable.
- Other sampling equipment - Bailers and inert line with tripod-pulley assembly (if necessary).
- Pails - Plastic, graduated.
- Decontamination solutions - Deionized water, potable water, laboratory detergents, 10% nitric acid solution (as required), and analytical-grade solvent (e.g., pesticide-grade isopropanol), as required.

Ideally, sample withdrawal equipment shall be completely inert, economical, easily cleaned, cleaned prior to use, reusable, able to operate at remote sites in the absence of power sources, and capable of delivering variable rates for well purging and sample collection.

5.3 Calculations of Well Volume

To insure that the proper volume of water has been removed from the well prior to sampling it is first necessary to know the volume of standing water in the well pipe. This volume can be easily calculated by the following method. Calculations shall be entered in the site logbook or field notebook or on a sample log sheet form (see SOP SA-6.3):

- Obtain all available information on well construction (location, casing, screens, etc.).
- Determine well or casing diameter.
- Measure and record static water level (depth below ground level or top of casing reference point).

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- Determine depth of well by sounding using a clean, decontaminated, weighted tape measure.
- Calculate number of linear feet of static water (total depth or length of well pipe minus the depth to static water level).
- Calculate one static well volume in gallons $V = (0.163)(T)(r^2)1$

where: V = Static volume of well in gallons.
T = Thickness of water table in the well measured in feet (i.e., linear feet of static water).
r = Inside radius of well casing in inches.
0.163 = A constant conversion factor which compensates for the conversion of the casing radius from inches to feet, the conversion of cubic feet to gallons, and pi.

- Per evacuation volumes discussed above, determine the minimum amount to be evacuated before sampling.

5.4 Evacuation of Static Water (Purging)

5.4.1 General

The amount of purging a well shall receive prior to sample collection will depend on the intent of the monitoring program and the hydrogeologic conditions. Programs to determine overall quality of water resources may require long pumping periods to obtain a sample that is representative of a large volume of that aquifer. The pumped volume may be specified prior to sampling so that the sample can be a composite of a known volume of the aquifer. Alternately the well can be pumped until the parameters such as temperature, specific conductance, pH, and turbidity (as applicable), have stabilized. Onsite measurements of these parameters shall be recorded in the site logbook, field notebook, or on standardized data sheets.

5.4.2 Evacuation Devices

The following discussion is limited to those devices commonly used at hazardous waste sites. Attachment A provides guidance on the proper evacuation device to use for given sampling situations. Note that all of these techniques involve equipment which is portable and readily available.

Bailers

Bailers are the simplest evacuation devices used and have many advantages. They generally consist of a length of pipe with a sealed bottom (bucket-type bailer) or, as is more useful and favored, with a ball check-valve at the bottom. An inert line is used to lower the bailer and retrieve the sample.

Advantages of bailers include:

- Few limitations on size and materials used for bailers.
- No external power source needed.
- Bailers are inexpensive, and can be dedicated and hung in a well to reduce the chances of cross-contamination.

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- There is minimal outgassing of volatile organics while the sample is in the bailer.
- Bailers are relatively easy to decontaminate.

Limitations on the use of bailers include the following:

- It is time consuming to remove stagnant water using a bailer.
- Transfer of sample may cause aeration.
- Use of bailers is physically demanding, especially in warm temperatures at protection levels above Level D.

Suction Pumps

There are many different types of inexpensive suction pumps including centrifugal, diaphragm, and peristaltic pumps. Centrifugal and diaphragm pumps can be used for well evacuation at a fast pumping rate and for sampling at a low pumping rate. The peristaltic pump is a low volume pump that uses rollers to squeeze a flexible tubing, thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination.

These pumps are all portable, inexpensive and readily available. However, because they are based on suction, their use is restricted to areas with water levels within 20 to 25 feet of the ground surface. A significant limitation is that the vacuum created by these pumps can cause significant loss of dissolved gases and volatile organics.

Air-Lift Samplers

This group of pump samplers uses gas pressure either in the annulus of the well or in a venturi to force the water up a sampling tube. These pumps are also relatively inexpensive. Air (or gas)-lift samplers are more suitable for well development than for sampling because the samples may be aerated, leading to pH changes and subsequent trace metal precipitation, or loss of volatile organics.

Submersible Pumps

Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these samplers may be compressed gas or electricity. The operation principles vary and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Pumps are available for 2-inch-diameter wells and larger. These pumps can lift water from considerable depths (several hundred feet).

Limitations of this class of pumps include:

- They may have low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electric power is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components can be difficult and time-consuming.

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5.5 Onsite Water Quality Testing

This section describes the procedures and equipment required to measure the following parameters of an aqueous sample in the field:

- pH
- Specific Conductance
- Temperature
- Dissolved Oxygen (DO)
- Oxidation Reduction Potential (ORP)
- Certain Dissolved Constituents Using Specific Ion Elements
- Turbidity
- Salinity

This section is applicable for use in an onsite groundwater quality monitoring program to be conducted at a hazardous or nonhazardous site. The procedures and equipment described are applicable to groundwater samples and are not, in general, subject to solution interferences from color, turbidity, and colloidal material or suspended matter.

This section provides general information for measuring the parameters listed above with instruments and techniques in common use. Since instruments from different manufacturers may vary, review of the manufacturer's literature pertaining to the use of a specific instrument is required before use.

5.5.1 Measurement of pH

5.5.1.1 General

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment such as acid-base neutralization, water softening, and corrosion control is pH dependent. Likewise, the pH of leachate can be correlated with other chemical analyses to determine the probable source of contamination. It is therefore important that reasonably accurate pH measurements be taken.

Two methods are given for pH measurement: the pH meter and pH indicator paper. The indicator paper is used when only a rough estimate of the pH is required, and the pH meter when a more accurate measurement is needed. The response of a pH meter can be affected to a slight degree by high levels of colloidal or suspended solids, but the effect is usually small and generally of little significance. Consequently, specific methods to overcome this interference are not described. The response of pH paper is unaffected by solution interferences from color, turbidity, colloidal or suspended materials unless extremely high levels capable of coating or masking the paper are encountered. In such cases, use of a pH meter is recommended.

5.5.1.2 Principles of Equipment Operation

Use of pH papers for pH measurement relies on a chemical reaction caused by the acidity or alkalinity of the solution created by the addition of the water sample reacting with the indicator compound on the paper. Various types of pH papers are available, including litmus (for general acidity or alkalinity determination) and specific pH range hydron paper.

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Use of a pH meter relies on the same principle as other ion-specific electrodes. Measurement relies on establishment of a potential difference across a glass or other type of membrane in response to (in this instance, hydrogen) ion concentration across that membrane. The membrane is conductive to ionic species and, in combination with a standard or reference electrode, a potential difference proportional to the ion concentration is generated and measured.

5.5.1.3 Equipment

The following equipment is needed for taking pH measurements:

- Stand-alone portable pH meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber (e.g., YSI 610).
- Combination electrode with polymer body to fit the above meter (alternately a pH electrode and a reference electrode can be used if the pH meter is equipped with suitable electrode inputs).
- Buffer solutions, as specified by the manufacturer.
- pH indicator paper, to cover the pH range 2 through 12.
- Manufacturer's operation manual.

5.5.1.4 Measurement Techniques for Field Determination of pH

pH Meter

The following procedure is used for measuring pH with a pH meter (meter standardization is according to manufacturer's instructions):

- Inspect the instrument and batteries prior to initiation of the field effort.
- Check the integrity of the buffer solutions used for field calibration. Buffer solutions need to be changed often as a result of degradation upon exposure to the atmosphere.
- If applicable, make sure all electrolyte solutions within the electrode(s) are at their proper levels and that no air bubbles are present within the electrode(s).
- Calibrate on a daily use basis (or as recommended by manufacturer) following manufacturer's instructions. Record calibration data on an equipment calibration log sheet.
- Immerse the electrode(s) in the sample, slowly stirring the probe until the pH stabilizes. Stabilization may take several seconds to minutes. If the pH continues to drift, the sample temperature may not be stable, a physical reaction (e.g., degassing) may be taking place in the sample, or the meter or electrode may be malfunctioning. This must be clearly noted in the logbook.
- Read and record the pH of the sample. pH shall be recorded to the nearest 0.01 pH unit. Also record the sample temperature.
- Rinse the electrode(s) with deionized water.
- Store the electrode(s) in an appropriate manner when not in use.

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Any visual observation of conditions which may interfere with pH measurement, such as oily materials, or turbidity, shall be noted.

pH Paper

Use of pH paper is very simple and requires no sample preparation, standardization, etc. pH paper is available in several ranges, including wide-range (indicating approximately pH 1 to 12), mid-range (approximately pH 0 to 6, 6 to 9, 8 to 14) and narrow-range (many available, with ranges as narrow as 1.5 pH units). The appropriate range of pH paper shall be selected. If the pH is unknown the investigation shall start with wide-range paper and proceed with successively narrower range paper until the sample pH is adequately determined.

5.5.2 Measurement of Specific Conductance

5.5.2.1 General

Conductance provides a measure of dissolved ionic species in water and can be used to identify the direction and extent of migration of contaminants in groundwater or surface water. It can also be used as a measure of subsurface biodegradation or to indicate alternate sources of groundwater contamination.

Conductivity is a numerical expression of the ability of a water sample to carry an electric current. This value depends on the total concentration of the ionized substances dissolved in the water and the temperature at which the measurement is made. The mobility of each of the various dissolved ions, their valences, and their actual and relative concentrations affect conductivity.

It is important to obtain a specific conductance measurement soon after taking a sample, since temperature changes, precipitation reactions, and absorption of carbon dioxide from the air all affect the specific conductance.

5.5.2.2 Principles of Equipment Operation

An aqueous system containing ions will conduct an electric current. In a direct-current field, the positive ions migrate toward the negative electrode, while the negatively charged ions migrate toward the positive electrode. Most inorganic acids, bases and salts (such as hydrochloric acid, sodium carbonate, or sodium chloride, respectively) are relatively good conductors. Conversely, organic compounds such as sucrose or benzene, which do not dissociate in aqueous solution, conduct a current very poorly, if at all.

A conductance cell and a Wheatstone Bridge (for the measurement of potential difference) may be used for measurement of electrical resistance. The ratio of current applied to voltage across the cell may also be used as a measure of conductance. The core element of the apparatus is the conductivity cell containing the solution of interest. Depending on ionic strength of the aqueous solution to be tested, a potential difference is developed across the cell which can be converted directly or indirectly (depending on instrument type) to a measurement of specific conductance.

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5.5.2.3 Equipment

The following equipment is needed for taking specific conductance (SC) measurements:

- Stand alone portable conductivity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber (e.g., YSI 610).
- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

A variety of conductivity meters are available which may also be used to monitor salinity and temperature. Probe types and cable lengths vary, so equipment must be obtained to meet the specific requirement of the sampling program.

5.5.2.4 Measurement Techniques for Specific Conductance

The steps involved in taking specific conductance measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Calibrate on a daily use basis (or as recommended by manufacturer), according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet. Potassium chloride solutions with a SC closest to the values expected in the field shall be used for calibration. Attachment B provides guidance in this regard.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the electrode in the sample and measure the conductivity. Adjust the temperature setting to the sample temperature (if applicable).
- Read and record the results in a field logbook or sample log sheet.
- Rinse the electrode with deionized water.

If the specific conductance measurements become erratic, recalibrate the instrument and see the manufacturer's instructions for details.

5.5.3 Measurement of Temperature

5.5.3.1 General

In combination with other parameters, temperature can be a useful indicator of the likelihood of biological action in a water sample. It can also be used to trace the flow direction of contaminated groundwater. Temperature measurements shall be taken in-situ, or as quickly as possible in the field. Collected water samples may rapidly equilibrate with the temperature of their surroundings.

5.5.3.2 Equipment

Temperature measurements may be taken with alcohol-toluene, mercury filled or dial-type thermometers. In addition, various meters such as specific conductance or dissolved oxygen meters, which have

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temperature measurement capabilities, may also be used. Using such instrumentation along with suitable probes and cables, in-situ measurements of temperature at great depths can be performed.

5.5.3.3 Measurement Techniques for Water Temperature

If a thermometer is used to determine the temperature for a water sample:

- Immerse the thermometer in the sample until temperature equilibrium is obtained (1-3 minutes). To avoid the possibility of cross-contamination, the thermometer shall not be inserted into samples which will undergo subsequent chemical analysis.
- Record values in a field logbook or sample log sheet.

If a temperature meter or probe is used, the instrument shall be calibrated according to manufacturer's recommendations.

5.5.4 Measurement of Dissolved Oxygen

5.5.4.1 General

Dissolved oxygen (DO) levels in natural water and wastewater depend on the physical, chemical and biochemical activities in the water body. Conversely, the growth of many aquatic organisms as well as the rate of corrosivity, are dependent on the dissolved oxygen concentration. Thus, analysis for dissolved oxygen is a key test in water pollution and waste treatment process control. If at all possible, DO measurements shall be taken in-situ, since concentration may show a large change in a short time if the sample is not adequately preserved.

The monitoring method discussed herein is limited to the use of dissolved oxygen meters only. Chemical methods of analysis (i.e., Winkler methods) are available, but require more equipment and greater sample manipulation. Furthermore, DO meters, using a membrane electrode, are suitable for highly polluted waters, because the probe is completely submersible, and is not susceptible to interference caused by color, turbidity, colloidal material or suspended matter.

5.5.4.2 Principles of Equipment Operation

Dissolved oxygen probes are normally electrochemical cells that have two solid metal electrodes of different nobility immersed in an electrolyte. The electrolyte is retained by an oxygen-permeable membrane. The metal of highest nobility (the cathode) is positioned at the membrane. When a suitable potential exists between the two metals, reduction of oxygen to hydroxide ion (OH⁻) occurs at the cathode surface. An electrical current is developed that is directly proportional to the rate of arrival of oxygen molecules at the cathode.

Since the current produced in the probe is directly proportional to the rate of arrival of oxygen at the cathode, it is important that a fresh supply of sample always be in contact with the membrane. Otherwise, the oxygen in the aqueous layer along the membrane is quickly depleted and false low readings are obtained. It is therefore necessary to stir the sample (or the probe) constantly to maintain fresh solution near the membrane interface. Stirring, however, shall not be so vigorous that additional oxygen is introduced through the air-water interface at the sample surface. To avoid this possibility, some probes are equipped with stirrers to agitate the solution near the probe, while leaving the surface of the solution undisturbed.

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Dissolved oxygen probes are relatively unaffected by interferences. Interferences that can occur are reactions with oxidizing gases (such as chlorine) or with gases such as hydrogen sulfide, which are not easily depolarized from the indicating electrode. If a gaseous interference is suspected, it shall be noted in the field log book and checked if possible. Temperature variations can also cause interference because probes exhibit temperature sensitivity. Automatic temperature compensation is normally provided by the manufacturer.

5.5.4.3 Equipment

The following equipment is needed to measure dissolved oxygen concentration:

- Stand alone portable dissolved oxygen meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber (e.g., YSI 610).
- Sufficient cable to allow the probe to contact the sample.
- Manufacturer's operation manual.

5.5.4.4 Measurement Techniques for Dissolved Oxygen Determination

Probes differ as to specifics of use. Follow the manufacturer's instructions to obtain an accurate reading. The following general steps shall be used to measure the dissolved oxygen concentration:

- The equipment shall be calibrated and have its batteries checked before going to the field.
- The probe shall be conditioned in a water sample for as long a period as practical before use in the field. Long periods of dry storage followed by short periods of use in the field may result in inaccurate readings.
- The instrument shall be calibrated in the field according to manufacturer's recommendations or in a freshly air-saturated water sample of known temperature. Dissolved oxygen values for air-saturated water can be determined by consulting a table listing oxygen solubilities as a function of temperature and salinity (see Attachment C).
- Record all pertinent information on an equipment calibration sheet.
- Rinse the probe with deionized water.
- Immerse the probe in the sample. Be sure to provide for sufficient flow past the membrane by stirring the sample. Probes without stirrers placed in wells can be moved up and down.
- Record the dissolved oxygen content and temperature of the sample in a field logbook or sample log sheet.
- Rinse the probe with deionized water.
- Recalibrate the probe when the membrane is replaced, or as needed. Follow the manufacturer's instructions.

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Note that in-situ placement of the probe is preferable, since sample handling is not involved. This however, may not always be practical. Be sure to record whether the liquid was analyzed in-situ, or if a sample was taken.

Special care shall be taken during sample collection to avoid turbulence which can lead to increased oxygen solubilization and positive test interferences.

5.5.5 Measurement of Oxidation-Reduction Potential

5.5.5.1 General

The oxidation-reduction potential (ORP) provides a measure of the tendency of organic or inorganic compounds to exist in an oxidized state. The ORP parameter therefore provides evidence of the likelihood of anaerobic degradation of biodegradable organics or the ratio of activities of oxidized to reduced species in the sample.

5.5.5.2 Principles of Equipment Operation

When an inert metal electrode, such as platinum, is immersed in a solution, a potential is developed at that electrode depending on the ions present in the solution. If a reference electrode is placed in the same solution, an ORP electrode pair is established. This electrode pair allows the potential difference between the two electrodes to be measured and is dependent on the concentration of the ions in solution. By this measurement, the ability to oxidize or reduce species in solution may be determined. Supplemental measurements, such as dissolved oxygen, may be correlated with ORP to provide a knowledge of the quality of the solution, water, or wastewater.

5.5.5.3 Equipment

The following equipment is needed for measuring the oxidation-reduction potential of a solution:

- Portable pH meter or equivalent, with a millivolt scale.
- Platinum electrode to fit above pH meter.
- Reference electrode such as a calomel, silver-silver chloride, or equivalent.
- Reference solution as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.5.4 Measurement Techniques for Oxidation-Reduction Potential

The following procedure is used for measuring oxidation-reduction potential:

- The equipment shall be calibrated and have its batteries checked before going to the field.
- Check that the platinum probe is clean and that the platinum bond or tip is unoxidized. If dirty, polish with emery paper or, if necessary, clean the electrode using aqua regia, nitric acid, or chromic acid, in accordance with manufacturer's instructions.
- Thoroughly rinse the electrode with deionized water.
- Verify the sensitivity of the electrodes by noting the change in millivolt reading when the pH of the test solution is altered. The ORP will increase when the pH of the test solution decreases, and the ORP

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will decrease if the test solution pH is increased. Place the sample in a clean container and agitate the sample. Insert the electrodes and note the ORP drops sharply when the caustic is added (i.e., pH is raised) thus indicating the electrodes are sensitive and operating properly. If the ORP increases sharply when the caustic is added, the polarity is reversed and must be corrected in accordance with the manufacturer's instructions. If the ORP does not respond as above when the caustic is added, the electrodes shall be cleaned and the above procedure repeated.

- After the assembly has been checked for sensitivity, wash the electrodes with three changes of water or by means of a flowing stream of deionized water from a wash bottle. Place the sample in a clean container and insert the electrodes. Set temperature compensator throughout the measurement period. Read the millivolt potential of the solution, allowing sufficient time for the system to stabilize and reach temperature equilibrium. Measure successive portions of the sample until readings on two successive portions differ by no more than 10 mV. A system that is very slow to stabilize properly will not yield a meaningful ORP. Record all results in a field logbook or sample logsheet, including ORP (to nearest 10 mV), sample temperature and pH at the time of measurement.

5.5.6 Measurement of Turbidity

5.5.6.1 General

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, and microscopic organisms, including plankton.

It is important to obtain a turbidity reading immediately after taking a sample, since irreversible changes in turbidity may occur if the sample is stored too long.

5.5.6.2 Principles of Equipment Operation

Turbidity is measured by the Nephelometric Method. This method is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions. The higher the scattered light intensity, the higher the turbidity.

Formazin polymer is used as the reference turbidity standard suspension because of its ease of preparation combined with a higher reproducibility of its light-scattering properties than clay or turbid natural water. The turbidity of a specified concentration of formazin suspension is defined as 40 nephelometric units. This same suspension has an approximate turbidity of 40 Jackson units when measured on the candle turbidimeter. Therefore, nephelometric turbidity units (NTU) based on the formazin preparation will approximate units derived from the candle turbidimeter but will not be identical to them.

5.5.6.3 Equipment

The following equipment is needed for turbidity measurement:

- Stand alone portable turbidity meter, or combination meter (e.g., Horiba U-10), or combination meter equipped with an in-line sample chamber (e.g., YSI 61).

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- Calibration solution, as specified by the manufacturer.
- Manufacturer's operation manual.

5.5.6.4 Measurement Techniques for Turbidity

The steps involved in taking turbidity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate instrument before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with one or more portions of the sample to be tested or with deionized water.
- Immerse the probe in the sample and measure the turbidity. The reading must be taken immediately as suspended solids will settle over time resulting in a lower, inaccurate turbidity reading.
- Read and record the results in a field logbook or sample log sheet. Include a physical description of the sample, including color, qualitative estimate of turbidity, etc.
- Rinse the electrode with deionized water.

5.5.7 Measurement of Salinity

5.5.7.1 General

Salinity is a unitless property of industrial and natural waters. It is the measurement of dissolved salts in a given mass of solution. Note: Most field meters determined salinity automatically from conductivity and temperature. The displayed value will be displayed in either parts per thousand (ppt) or ‰ (e.g., 35 ppt will equal 3.5%).

5.5.7.2 Principles of Equipment Operation

Salinity is determined automatically from the meter's conductivity and temperature readings according to algorithms (found in *Standard methods for the Examination of Water and Wastewater*). Depending on the meter, the results are displayed in either ppt or ‰. The salinity measurements are carried out in reference to the conductivity of standard seawater (corrected to S = 35).

5.5.7.3 Equipment

The following equipment is needed for Salinity measurements:

- Multi-parameter water quality meter capable of measuring conductive, temperature and converting them to salinity (e.g., Horiba U-10 or YSI 610).
- Calibration Solution, as specified by the manufacturer.
- Manufacturer's operation manual.

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5.5.7.4 Measurement Techniques for Salinity

The steps involved in taking Salinity measurements are listed below (standardization is according to manufacturer's instructions):

- Check batteries and calibrate before going into the field.
- Check the expiration date (etc.) of the solutions used for field calibration.
- Calibrate on a daily use basis, according to the manufacturer's instructions and record all pertinent information on an equipment calibration log sheet.
- Rinse the cell with the sample to be tested.
- Immerse the probes in the sample and measure the salinity. Read and record the results in a field logbook or sample log sheet.
- Rinse the probes with deionized water.

5.6 Sampling

5.6.1 Sampling Plan

The sampling approach consisting of the following, shall be developed as part of the project plan documents which are approved prior to beginning work in the field:

- Background and objectives of sampling.
- Brief description of area and waste characterization.
- Identification of sampling locations, with map or sketch, and applicable well construction data (well size, depth, screened interval, reference elevation).
- Intended number, sequence volumes, and types of samples. If the relative degree of contamination between wells is unknown or insignificant, a sampling sequence which facilitates sampling logistics may be followed. Where some wells are known or strongly suspected of being highly contaminated, these shall be sampled last to reduce the risk of cross-contamination between wells as a result of the sampling procedures.
- Sample preservation requirements.
- Work schedule.
- List of team members.
- List of observers and contacts.
- Other information, such as the necessity for a warrant or permission of entry, requirement for split samples, access problems, location of keys, etc.

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5.6.2 Sampling Methods

The collection of a groundwater sample consists of the following steps:

1. The site Health & Safety Officer (or designee) will first open the well cap and use volatile organic detection equipment (PID or FID) on the escaping gases at the well head to determine the need for respiratory protection.
2. When proper respiratory protection has been donned, sound the well for total depth and water level (using clean equipment) and record these data on a groundwater sampling log sheet (see SOP SA-6.3); then calculate the fluid volume in the well pipe (as previously described in this SOP).
3. Calculate well volume to be removed as stated in Section 5.3.
4. Select the appropriate purging equipment (see Attachment A). If an electric submersible pump with packer is chosen, go to Step 10.
5. Lower the purging equipment or intake into the well to a short distance below the water level and begin water removal. Collect the purged water and dispose of it in an acceptable manner (as applicable). Lower the purging device, as required, to maintain submergence.
6. Measure the rate of discharge frequently. A graduated bucket and stopwatch are most commonly used; other techniques include use of pipe trajectory methods, weir boxes or flow meters.
7. Observe the peristaltic pump intake for degassing "bubbles." If bubbles are abundant and the intake is fully submerged, this pump is not suitable for collecting samples for volatile organics.
8. Purge a minimum of three to five casing volumes before sampling. In low-permeability strata (i.e., if the well is pumped to dryness), one volume will suffice. Purged water shall be collected in a designated container and disposed in an acceptable manner.
9. If sampling using a pump, lower the pump intake to midscreen (or the middle of the open section in uncased wells) and collect the sample. If sampling with a bailer, lower the bailer to just below the water surface.
10. (For pump and packer assembly only). Lower the assembly into the well so that the packer is positioned just above the screen or open section. Inflate the packer. Purge a volume equal to at least twice the screened interval (or unscreened open section volume below the packer) before sampling. Packers shall always be tested in a casing section above ground to determine proper inflation pressures for good sealing.
11. In the event that recovery time of the well is very slow (e.g., 24 hours or greater), sample collection can be delayed until the following day. If the well has been purged early in the morning, sufficient water may be standing in the well by the day's end to permit sample collection. If the well is incapable of producing a sufficient volume of sample at any time, take the largest quantity available and record this occurrence in the site logbook.
12. Fill sample containers (preserve and label as described in SOP SA-6.1).

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13. Replace the well cap and lock as appropriate. Make sure the well is readily identifiable as the source of the samples.
14. Process sample containers as described in SOP SA-6.1.
15. Decontaminate equipment as described in SOP SA-7.1.

6.7 Low Flow Purging and Sampling

6.7.1 Scope & Application

Low flow purging and sampling techniques are sometimes required for groundwater sampling activities. The purpose of low flow purging and sampling is to collect groundwater samples that contain "representative" amounts of mobile organic and inorganic constituents in the vicinity of the selected open well interval, at near natural flow conditions. The minimum stress procedure emphasizes negligible water level drawdown and low pumping rates in order to collect samples with minimal alterations in water chemistry. This procedure is designed primarily to be used in wells with a casing diameter of 2 inches or more and a saturated screen, or open interval, length of ten feet or less. Samples obtained are suitable for analyses of common types of groundwater contaminants (volatile and semi-volatile organic compounds, pesticides, PCBs, metals and other inorganic ions [cyanide, chloride, sulfate, etc.]). This procedure is not designed to collect non-aqueous phase liquids samples from wells containing light or dense non-aqueous phase liquids (LNAPLs or DNAPLs), using the low flow pumps.

The procedure is flexible for various well construction types and groundwater yields. The goal of the procedure is to obtain a turbidity level of less than 5 NTU and to achieve a water level drawdown of less than 0.3 feet during purging and sampling. If these goals cannot be achieved, sample collection can take place provided the remaining criteria in this procedure are met.

6.7.2 Equipment

The following equipment is required (as applicable) for low flow purging and sampling:

- Adjustable rate, submersible pump (e.g., centrifugal or bladder pump constructed of stainless steel or Teflon).
- Disposable clear plastic bottom filling bailers may be used to check for and obtain samples of LNAPLs or DNAPLs.
- Tubing - Teflon, Teflon-lined polyethylene, polyethylene, PVC, Tygon, stainless steel tubing can be used to collect samples for analysis, depending on the analyses to be performed and regulatory requirements.
- Water level measuring device, 0.01 foot accuracy, (electronic devices are preferred for tracking water level drawdown during all pumping operations).
- Flow measurement supplies.
- Interface probe, if needed.

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- Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at a safe distance from the well so that the exhaust fumes do not contaminate the samples.
- Indicator parameter monitoring instruments - pH, turbidity, specific conductance, and temperature. Use of a flow-through cell is recommended. Optional Indicators - ORP and dissolved oxygen, flow-through cell is required. Standards to perform field calibration of instruments.
- Decontamination supplies.
- Logbook(s), and other forms (e.g., well purging forms).
- Sample Bottles.
- Sample preservation supplies (as required by the analytical methods).
- Sample tags and/or labels.
- Well construction data, location map, field data from last sampling event.
- Field Sampling Plan.
- PID or FID instrument for measuring VOCs (volatile organic compounds).

5.7.3 Purging and Sampling Procedure

Use a submersible pump to purge and sample monitoring wells which have a 2.0 inch or greater well casing diameter.

Measure and record the water level immediately prior to placing the pump in the well.

Lower pump, safety cable, tubing and electrical lines slowly into the well so that the pump intake is located at the center of the saturated screen length of the well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of sediment that may be present in the bottom of the well. Collection of turbidity-free water samples may be difficult if there is three feet or less of standing water in the well.

When starting the pump, slowly increase the pump speed until a discharge occurs. Check water level. Adjust pump speed to maintain little or no water level drawdown. The target drawdown should be less than 0.3 feet and it should stabilize. If the target of less than 0.3 feet cannot be achieved or maintained, the sampling is acceptable if remaining criteria in the procedure are met. Subsequent sampling rounds will probably have intake settings and extraction rates that are comparable to those used in the initial sampling rounds.

Monitor water level and pumping rate every five to ten minutes (or as appropriate) during purging. Record pumping rate adjustments and depths to water. Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (e.g., 0.1-0.2 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During initial pump start-up, drawdown may exceed the 0.3 feet target and then recover as pump flow adjustments are made (minimum purge volume calculations should utilize stabilized drawdown values, not the initial drawdown). If the recharge rate of the well is less than minimum capability of the pump do not

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allow the water level to fall to the intake level (if the static water level is above the screen, avoid lowering the water level into the screen). Shut off the pump if either of the above is about to occur and allow the water level to recover. Repeat the process until field indicator parameters stabilize and the minimum purge volume is removed. The minimum purge volume with negligible drawdown (0.3 feet or less) is two saturated screen length volumes. In situations where the drawdown is greater than 0.3 feet and has stabilized, the minimum purge volume is two times the saturated screen volume plus the stabilized drawdown volume. After the minimum purge volume is attained (and field parameters have stabilized) begin sampling. For low yields wells, commence sampling as soon as the well has recovered sufficiently to collect the appropriate volume for all anticipated samples.

During well purging, monitor field indicator parameters (turbidity, temperature, specific conductance, pH, etc.) every five to ten minutes (or as appropriate). Purging is complete and sampling may begin when all field indicator parameters have stabilized (variations in values are within ten percent of each other, pH +/- 0.2 units, for three consecutive readings taken at five to ten minute intervals). If the parameters have stabilized, but turbidity remains above 5 NTU goal, decrease pump flow rate, and continue measurement of parameters every five to ten minutes. If pumping rate cannot be decreased any further and stabilized turbidity values remain above 5 NTU goal record this information. Measurements of field parameters should be obtained (as per Section 5.5) and recorded.

VOC samples are preferably collected first, directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the water column in the pump tubing collapses (water does not completely fill the tubing) before exiting the tubing, use one of the following procedures to collect VOC samples: (1) Collect the non-VOCs samples first, then increase the flow rate incrementally until the water column completely fills the tubing, collect the sample and record the new flow rate; (2) reduce the diameter of the existing tubing until the water column fills the tubing either by adding a connector (Teflon or stainless steel), or clamp which should reduce the flow rate by constricting the end of the tubing; (3) insert a narrow diameter Teflon tube into the pump's tubing so that the end of the tubing is in the water column and the other end of the tubing protrudes beyond the pump's tubing, collect sample from the narrow diameter tubing.

Prepare samples for shipping as per SOP SA-6.1.

5.6 REFERENCES

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ATTACHMENT A
PURGING EQUIPMENT SELECTION

Diameter Casing		Bailer	Peristaltic Pump	Vacuum Pump	Air-lift	Diaphragm "Trash" Pump	Submersible Diaphragm Pump	Submersible Electric Pump	Submersible Electric Pump w/Packer
1.25-Inch	Water level <25 feet		X	X	X	X			
	Water Level >25 feet				X				
2-Inch	Water level <25 feet	X	X	X	X	X	X		
	Water Level >25 feet	X			X		X		
4-Inch	Water level <25 feet	X	X	X	X	X	X	X	X
	Water Level >25 feet	X			X		X	X	X
6-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X
8-Inch	Water level <25 feet				X	X		X	X
	Water Level >25 feet				X			X	X

ATTACHMENT A
PURGING EQUIPMENT SELECTION
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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter, length (Inches)	Construction Materials (w/Lines and Tubing)	Lift Range (ft)	Delivery Rates or Volumes	1982 Price (Dollars)	Comments
BarCad Systems, Inc.	BarCad Sampler	Dedicated; gas drive (positive displacement)	1.5/16	PE, brass, nylon, aluminum oxide	0-150 with std. tubing	1 liter for each 10-15 feet of submergence	\$220-350	Requires compressed gas; custom sizes and materials available; acts as piezometer.
Cole-Parmer Inst. Co.	Master Flex 7570 Portable Sampling Pump	Portable; peristaltic (suction)	<1.0 NA	(not submersible) Tygon®, silicone, Viton®	0-30	670 mL/min with 7015-20 pump head	\$500-600	AC/DC; variable speed control available; other models may have different flow rates.
ECO Pump Corp.	SAMPLifier	Portable; venturi	<1.5 or <2.0 NA	PP, PE, PVC, SS, Teflon®, Tefzel®	0-100	0-500 mL/min depending on lift	\$400-700	AC, DC, or gasoline-driven motors available; must be primed.
Geltek Corp.	Baker 219-4	Portable; grab (positive displacement)	1.68/38	Teflon®	No limit	1,075 mL	\$120-135	Other sizes available.
GeoEngineering, Inc.	GEO-MONITOR	Dedicated; gas drive (positive displacement)	1.5/16	PE, PP, PVC, Viton®	Probably 0-150	Approximately 1 liter for each 10 feet of submergence	\$185	Acts as piezometer; requires compressed gas.
Industrial and Environmental Analysts, Inc. (IEA)	Aquarius	Portable; bladder (positive displacement)	1.75/43	SS, Teflon®, Viton®	0-250	0-2,800 mL/min	\$1,500-3,000	Requires compressed gas; other models available; AC, DC, manual operation possible.
IEA	Syringe Sampler	Portable; grab (positive displacement)	1.75/43	SS, Teflon®	No limit	850 mL sample volume	\$1,100	Requires vacuum and/or pressure from hand pump.
Instrument Specialties Co. (ISCO)	Model 2800 Well Sampler	Portable; bladder (positive displacement)	1.75/50	PC, silicone, Teflon®, PP, PE, Detrin®, acetal	0-150	0-7,500 mL/min	\$990	Requires compressed gas (40 psi minimum).
Kock Geophysical Instruments, Inc.	SP-81 Submersible Sampling Pump	Portable; helical rotor (positive displacement)	1.75/25	SS, Teflon®, PP, EPDM, Viton®	0-180	0-4,500 mL/min	\$3,500	DC operated.
Leonard Mold and Die Works, Inc.	GeoFilter Small Diameter Well Pump (#0500)	Portable; bladder (positive displacement)	1.75/38	SS, Teflon®, PC, Neoprene®	0-400	0-3,500 mL/min	\$1,400-1,500	Requires compressed gas (55 psi minimum); pneumatic or AC/DC control module.
Oil Recovery Systems, Inc.	Surface Sampler	Portable; grab (positive displacement)	1.75/12	acrylic, Detrin®	No limit	Approximately 250 mL	\$125-180	Other materials and models available, for measuring thickness of "floating" contaminants.
O.E.D. Environmental Systems, Inc.	Well Wizard® Monitoring System (P-100)	Dedicated; bladder (positive displacement)	1.68/38	PVC	0-230	0-2,000 mL/min	\$300-400	Requires compressed gas; piezometric level indicator; other materials available.

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ATTACHMENT A
PURGING EQUIPMENT SELECTION
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Manufacturer	Model Name/Number	Principle of Operation	Maximum Outside Diameter, inch (Inches)	Construction Materials (w/ Lines and Tubing)	Lit Range (ft)	Delivery Rates or Volumes	1992 Price (Dollars)	Comments
Randolph Austin Co.	Model 600 Vent-Flow Pump	Portable; peristaltic (function)	<0.5NA	(Not submersible) Rubber, Tygon®, or Neoprene®	0-30	See comments	\$1,200-1,300	Flow rate dependent on motor and tubing selected; AC operated; other models available.
Robert Bennett Co.	Model 160	Portable; piston (displacement)	1.3/22	SS, Teflon®, Delrin® PP, Viton®, acrylic, PE	0-500	0-1,800 mL/min	\$2,600-2,700	Requires compressed gas; water level indicator and flow meter; custom models available.
Slope Indicator Co. (SINCO)	Model 314124 Pneumatic Water Sampler	Portable; gas drive (displacement)	1.5/18	PVC, nylon	0-1,100	250 mL/flushing cycle	\$250-350	Requires compressed gas; SS available; piezometer model available; dedicated model available.
Solinst Canada Ltd.	SW Water Sampler	Portable; grab (displacement)	1.5/27	PVC, brass, nylon, Neoprene®	0-330	500 mL	\$1,300-1,800	Requires compressed gas; custom models available.
TMCO Mfg. Co., Inc.	Sol. Baller	Portable; grab (displacement)	1.25/Custom m	PVC, PP	No limit	250 mL/ft of bailer	\$20-60	Other sizes, materials, models available; optional bottom-employing device available; no solvents used.
TMCO	Air or Gas Lit Sampler	Portable; gas drive (displacement)	1.55/30	PVC, Tygon®, Teflon®	0-150	350 mL/flushing cycle	\$100-200	Requires compressed gas; other sizes, materials, models available; no solvents used.
Tole Devices Co.	Sampling Pump	Portable; bladder (displacement)	1.35/48	SS, silicone, Delrin®, Tygon®	0-125	0-4,000 mL/min	\$800-1,000	Compressed gas required; DC control module; custom built.

Construction Material Abbreviations:

PE Polyethylene
PP Polypropylene
PVC Polyvinyl chloride
SS Stainless steel
PC Polycarbonate
EPDM Ethylene-propylene diene (synthetic rubber)

Other Abbreviations:

NA Not applicable
AC Alternating current
DC Direct current

NOTE: Other manufacturers market pumping devices which could be used for groundwater sampling, though not expressly designed for this purpose. The list is not meant to be all-inclusive and listing does not constitute endorsement for use. Information in the table is from sales literature and/or personal communication. No skimmer, scavenger-type, or high-capacity pumps are included.

Sources: Barcelona et al., 1993.

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ATTACHMENT B

SPECIFIC CONDUCTANCE OF 1 MOLAR KCl AT VARIOUS TEMPERATURES¹

Temperature (°C)	Specific Conductance (umhos/cm)
15	1,147
16	1,173
17	1,199
18	1,225
19	1,251
20	1,278
21	1,305
22	1,332
23	1,359
24	1,368
25	1,413
26	1,441
27	1,468
28	1,496
29	1,524
30	1,552

¹ Data derived from the International Critical
Tables 1-3-8.

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ATTACHMENT C

VARIAION OF DISSOLVED OXYGEN CONCENTRATION IN WATER AS A FUNCTION OF TEMPERATURE AND SALINITY

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
0	14.6	13.8	13.0	12.1	11.3	0.017
1	14.2	13.4	12.6	11.8	11.0	0.016
2	13.8	13.1	12.3	11.5	10.8	0.015
3	13.5	12.7	12.0	11.2	10.5	0.015
4	13.1	12.4	11.7	11.0	10.3	0.014
5	12.8	12.1	11.4	10.7	10.0	0.014
6	12.5	11.8	11.1	10.5	9.8	0.014
7	12.2	11.5	10.9	10.2	9.6	0.013
8	11.9	11.2	10.6	10.0	9.4	0.013
9	11.6	11.0	10.4	9.8	9.2	0.012
10	11.3	10.7	10.1	9.6	9.0	0.012
11	11.1	10.5	9.9	9.4	8.8	0.011
12	10.8	10.3	9.7	9.2	8.6	0.011
13	10.6	10.1	9.5	9.0	8.5	0.011
14	10.4	9.9	9.3	8.8	8.3	0.010
15	10.2	9.7	9.1	8.6	8.1	0.010
16	10.0	9.5	9.0	8.5	8.0	0.010
17	9.7	9.3	8.8	8.3	7.8	0.010
18	9.5	9.1	8.6	8.2	7.7	0.009
19	9.4	8.9	8.5	8.0	7.6	0.009
20	9.2	8.7	8.3	7.9	7.4	0.009
21	9.0	8.6	8.1	7.7	7.3	0.009
22	8.8	8.4	8.0	7.6	7.1	0.008
23	8.7	8.3	7.9	7.4	7.0	0.008
24	8.5	8.1	7.7	7.3	6.9	0.008
25	8.4	8.0	7.6	7.2	6.7	0.008

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ATTACHMENT C
VARIATION OF DISSOLVED OXYGEN CONCENTRATION IN WATER
AS A FUNCTION OF TEMPERATURE AND SALINITY
PAGE TWO

Temperature (°C)	Dissolved Oxygen (mg/L)					
	Chloride Concentration in Water					Difference/ 100 mg Chloride
	0	5,000	10,000	15,000	20,000	
26	8.2	7.8	7.4	7.0	6.6	0.008
27	8.1	7.7	7.3	6.9	6.5	0.008
28	7.9	7.5	7.1	6.8	6.4	0.008
29	7.8	7.4	7.0	6.6	6.3	0.008
30	7.6	7.3	6.9	6.5	6.1	0.008
31	7.5					
32	7.4					
33	7.3					
34	7.2					
35	7.1					
36	7.0					
37	6.9					
38	6.8					
39	6.7					
40	6.6					
41	6.5					
42	6.4					
43	6.3					
44	6.2					
45	6.1					
46	6.0					
47	5.9					
48	5.8					
49	5.7					
50	5.6					

Note: In a chloride solution, conductivity can be roughly related to chloride concentration (and therefore, used to correct measured D.O. concentration) using Attachment B.



TETRA TECH NUS, INC.

STANDARD OPERATING PROCEDURES

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Applicability	Tetra Tech NUS, Inc.		
Prepared	Earth Sciences Department		
Approved	D. Senovich <i>JS</i>		

Subject
SOIL SAMPLING

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B REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING	18

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1.0 PURPOSE

This procedure discusses the methods used to collect surface, near surface, and subsurface soil samples. Additionally, it describes the method for sampling of test pits and trenches to determine subsurface soil and rock conditions, and recover small-volume or bulk samples.

2.0 SCOPE

This procedure is applicable to the collection of surface, near surface and subsurface soils for laboratory testing, which are exposed through hand digging, hand augering, drilling, or machine excavating at hazardous substance sites.

3.0 GLOSSARY

Composite Sample - A composite sample exists as a combination of more than one sample at various locations and/or depths and times, which is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples are not to be collected for volatile organics analysis.

Grab Sample - One sample collected at one location and at one specific time.

Non-Volatile Sample - A non-volatile sample includes all other chemical parameters (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

Hand Auger - A sampling device used to extract soil from the ground in a relatively undisturbed form.

Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-barrel sampler is typically available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-barrel samplers commonly range in size from 2-inch OD to 3-1/2 inch OD. The larger sizes are commonly used when a larger volume of sample material is required.

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine the shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher excavator, or bulldozer).

Confined Space - As stipulated in 29 CFR 1910.146, a confined space means a space that: 1) is large enough and so configured that an employee can bodily enter and perform assigned work; 2) has limited or restricted means for entry or exit (for example tanks, vessels, silos, storage bins, hoppers, vaults, and pits, and excavations are spaces that may have limited means of entry.); and 3) is not designed for continuous employee occupancy. TTNUS considers all confined space as permit-required confined spaces.

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4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for determining sampling objectives, as well as, the field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches, and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan. This will include (but not be limited to) performing air quality monitoring during sampling, boring and excavation activities, and to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - The FOL is responsible for finalizing the location of surface, near surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits and trenches, and for adherence to OSHA regulations during these operations.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of soil samples and the completion of all required paperwork (i.e., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms).

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

5.0 PROCEDURES

5.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they have migrated into the water table, and can establish the amount of contamination sorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can affect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during the sampling operations, particularly noting the location, depth, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. As a result, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers, and be analyzed as soon as possible.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. Often this information on soil properties can be obtained from published soil

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surveys available through the U.S. Geological Surveys and other government or farm agencies. It is the intent of this procedure to present the most commonly employed soil sampling methods used at hazardous waste sites.

5.2 Soil Sample Collection

5.2.1 Procedure for Collecting Soil Samples for Volatile Organic Compounds

The above described traditional sampling techniques, used for the collection of soil samples for volatile organic analysis, have recently been evaluated by the scientific community and determined to be ineffective in producing accurate results (biased low) due to the loss of volatile organics in the sampling stages and microbial degradation of aromatic volatiles. One of the newly adopted sampling procedures for collecting soil samples includes the field preservation of samples with methanol or sodium bisulfate to minimize volatilization and biodegradation. These preservation methods may be performed either in the field or laboratory, depending on the sampling methodology employed.

Soil samples to be preserved by the laboratory are currently being performed using method SW-846, 5035. Laboratories are currently performing low level analyses (sodium bisulfate preservation) and high level analyses (methanol preservation) depending on the end users needs.

It should be noted that a major disadvantage of the methanol preservation method is that the laboratory reporting limits will be higher than conventional testing. The reporting levels using the new method for most analytes are 0.5 µg/g for GC/MS and 0.05 µg/g for GC methods.

The alternative preservation method for collecting soil samples is with sodium bisulfate. This method is more complex to perform in the field and therefore is not preferred for field crews. It should also be noted that currently, not all laboratories have the capabilities to perform this analysis. The advantage to this method is that the reporting limits (0.001 µg/g for GC/PID or GC/ELCD, or 0.010 for GC/MS) are lower than those described above.

The following procedures outline the necessary steps for collecting soil samples to be preserved at the laboratory, and for collecting soil samples to be preserved in the field with methanol or sodium bisulfate.

5.2.1.1 Soil Samples to be Preserved at the Laboratory

Soil samples collected for volatile organics that are to be preserved at the laboratory will be obtained using a hermetically sealed sample vial such as an EnCore™ sampler. Each sample will be obtained using a reusable sampling handle provided with the EnCore™ sampler. The sample is collected by pushing the EnCore™ sampler directly into the soil, ensuring that the sampler is packed tight with soil, leaving zero headspace. Using this type of sampling device eliminates the need for field preservation and the shipping restrictions associated with preservatives.

Once the sample is collected, it should be placed on ice immediately and shipped to the laboratory within 48 hours (following the chain-of-custody and documentation procedures outlined in SOP SA-6.1). Samples must be preserved by the laboratory within 48 hours of sample collection.

If the lower detection limits are necessary, an option would be to collect several EnCore™ samplers at a given sample location. Send all samplers to the laboratory and the laboratory can perform the required preservation and analyses.

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5.2.1.2 Soil Samples to be Preserved in the Field

Soil samples preserved in the field may be prepared for analyses using both the low-level (sodium bisulfate preservation) method and medium-level (methanol preservation) method.

Methanol Preservation (Medium Level):

Soil samples to be preserved in the field with methanol will utilize 40-60 mL glass vials with septum lids. Each sample bottle will be filled with 25 mL of demonstrated analyte-free purge and trap grade methanol. Bottles may be prespiked with methanol in the laboratory or prepared in the field.

Soil will be collected with the use of a decontaminated (or disposable), small-diameter coring device such as a disposable tube/plunger-type syringe with the tip cut off. The outside diameter of the coring device must be smaller than the inside diameter of the sample bottle neck.

A small electronic balance or manual scale will be necessary for measuring the volume of soil to be added to the methanol preserved sample bottle. Calibration of the scale should be performed prior to use and intermittently throughout the day according to the manufacturers requirements.

The sample should be collected by pulling the plunger back and inserting the syringe into the soil to be sampled. The top several inches of soil should be removed before collecting the sample. Approximately 10 grams +2g (8-12 grams) of soil should be collected. The sample should be weighed and adjusted until obtaining the required amount of sample. The sample weight should be recorded to the nearest 0.01 gram in the field logbook and/or sample log sheet. The soil should then be extruded into the methanol preserved sample bottle taking care not to contact the sample container with the syringe. The threads of the bottle and cap must be free of soil particles.

After capping the bottle, swirl the sample (do not shake) in the methanol and break up the soil such that all of the soil is covered with methanol. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

Sodium Bisulfate Preservation (Low Level):

Samples to be preserved using the sodium bisulfate method are to be prepared as follows:

Add 1 gram of sodium bisulfate to 5 mL of laboratory grade deionized water in a 40-60 mL glass vial with septum lid. Bottles may be prespiked in the laboratory or prepared in the field. The soil sample should be collected in a manner as described above and added to the sample container. The sample should be weighed to nearest 0.01 gram as described above and recorded in field logbook or sample log sheet.

Care should be taken when adding the soil to the sodium bisulfate solution. A chemical reaction of soils containing carbonates (limestone) may cause the sample to effervesce or the vial to possibly explode.

When preparing samples using the sodium bisulfate preservation method, duplicate samples must be collected using the methanol preservation method on a one for one sample basis. The reason for this is because it is necessary for the laboratory to perform both the low level and medium level analyses. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

If the lower detection limits are necessary, an option to field preserving with sodium bisulfate would be to collect 3 EnCore™ samplers at a given sample location. Send all samplers to the laboratory and the laboratory can perform the required preservation and analyses.

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5.2.2 Procedure for Collecting Non-Volatile Soil Samples

Non-volatile soil samples may be collected as either grab or composite samples. The non-volatile soil sample is thoroughly mixed in a stainless steel or disposable, inert plastic tray, using a stainless steel trowel or other approved tool, then transferred into the appropriate sample container(s). Head space is permitted in a non-volatile soil sample container to allow for sample expansion.

5.2.3 Procedure for Collecting Undisturbed Soil Samples (ASTM D1587-83)

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) will be employed. The following method will be used:

1. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and clean out the borehole to the sampling depth, being careful to minimize the chance for disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.
2. The use of bottom discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Use of any side-discharge bits is permitted.
3. A stationary piston-type sampler may be required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used. Prior to inserting the tube sampler into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal and to maintain a suction within the tube to help retain the sample.
4. To minimize chemical reaction between the sample and the sampling tube, brass tubes may be required, especially if the tube is stored for an extended time prior to testing. While steel tubes coated with shellac are less expensive than brass, they're more reactive, and shall only be used when the sample will be tested within a few days after sampling or if chemical reaction is not anticipated. With the sampling tube resting on the bottom of the hole and the water level in the boring at groundwater level or above, push the tube into the soil by a continuous and rapid motion, without impacting or twisting. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.
5. Upon removal of the sampling tube from the hole, measure the length of sample in the tube and also the length penetrated. Remove disturbed material in the upper end of the tube and measure the length of sample again. After removing at least an inch of soil from the lower end and after inserting an impervious disk, seal both ends of the tube with at least a 1/2-inch thickness of wax applied in a way that will prevent the wax from entering the sample. Clean filler must be placed in voids at either end of the tube prior to sealing with wax. Place plastic caps on the ends of the sample tube, tape the caps in place, and dip the ends in wax.
6. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label. Mark the "up" direction on the side of the tube with indelible ink, and mark the end of the sample. Complete Chain-of-Custody and other required forms (see SOP SA-8.3). Do not allow tubes to freeze, and store the samples vertically with the same orientation they had in the

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ground, (i.e., top of sample is up) in a cool place out of the sun at all times. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

Thin-walled undisturbed tube samplers are restricted in their usage by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soils with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dennison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soils. Using these devices normally increases sampling costs, and therefore their use shall be weighed against the need for acquiring an undisturbed sample.

5.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples (most commonly collected to a depth of 6 inches) for subsequent analysis is by use of a stainless steel trowel. Surface soils are considered 0-12 inches bgs.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel or pre-cleaned disposable trowel.
- Real-time air monitoring instrument (e.g., PID, FID, etc.).
- Latex gloves.
- Required Personal Protective Equipment (PPE).
- Required paperwork.
- Required decontamination equipment.
- Required sample container(s).
- Wooden stakes or pin flags.
- Sealable polyethylene bags (i.e., Ziploc® baggies).
- Heavy duty cooler.
- Ice (if required) double-bagged in sealable polyethylene bags.
- Chain-of-custody records and custody seals.

When acquiring surface soil samples, the following procedure shall be used:

1. Carefully remove vegetation, roots, twigs, litter, etc., to expose an adequate soil surface area to accommodate sample volume requirements.
2. Using a decontaminated stainless steel trowel, follow the procedure cited in Section 5.2.1 for collecting a volatile soil sample. Surface soil samples for volatile organic analysis should be collected from 6-12 inches bgs only.
3. Thoroughly mix (in-situ) a sufficient amount of soil to fill the remaining sample containers and transfer the sample into those containers utilizing the same stainless steel trowel employed above. Cap and securely tighten all sample containers.
4. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.
5. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.

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5.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6-18 inches) can be accomplished with tools such as shovels and stainless steel or pre-cleaned disposable trowels.

The following equipment is necessary to collect near surface soil samples:

- Clean shovel.
- The equipment listed under Section 5.3 of this procedure.
- Hand auger.

To obtain near-surface soil samples, the following protocol shall be observed:

1. With a clean shovel, make a series of vertical cuts to the depth required in the soil to form a square approximately 1 foot by 1 foot.
2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel or pre-cleaned disposable trowel to remove any loose soil.
3. Follow steps 2 through 5 listed under Section 5.3 of this procedure.

5.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of all stainless steel bucket bits (i.e., cylinders 6-1/2" long, and 2-3/4", 3-1/4", and 4" in diameter), a series of extension rods (available in 2', 3', 4' and 5' lengths), and a cross handle. A larger diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then withdrawn. In turn, the larger diameter bit is replaced with a smaller diameter bit, lowered down the hole, and slowly turned into the soil at the completion depth (approximately 6"). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil both from the surface, or to depths in excess of 12 feet. However, the presence of rock layers and the collapse of the borehole normally contribute to its limiting factors.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes).
- Stainless steel mixing bowls.
- The equipment listed under Section 5.3 of this procedure.

To obtain soil samples using a hand auger, the following procedure shall be followed:

1. Attach a properly decontaminated bucket bit to a clean extension rod and further attach the cross handle to the extension rod.
2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).
3. Begin augering (periodically removing accumulated soils from the bucket bit) and add additional rod extensions as necessary. Also, note (in a field notebook or on standardized data sheets) any changes in the color, texture or odor of the soil.

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4. After reaching the desired depth, slowly and carefully withdraw the apparatus from the borehole.
5. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is commonly smaller in diameter than the bucket bit employed to initiate the borehole.
6. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.
7. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.
8. Discard the top of the core (approximately 1"), which represents any loose material collected by the bucket bit before penetrating the sample material.
9. Fill volatile sample container(s), using a properly decontaminated stainless steel trowel, with sample material directly from the bucket bit. Refer to Section 5.2.1 of this procedure.
10. Utilizing the above trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl and thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.
11. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.6 Subsurface Soil Sampling With a Split-Barrel Sampler (ASTM D1586-84)

Split-barrel (split-spoon) samplers consist of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment A). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-lb. or larger casing driver.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (O.D. 2 inches, I.D. 1-3/8 inches, either 20 inches or 26 inches long); Larger O.D. samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-lb. weight, driving head and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Equipment listed under Section 5.3 of this procedure.

The following steps shall be followed to obtain split-barrel samples:

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1. Remove the drive head and nosepiece, and open the sampler to reveal the soil sample. Immediately scan the sample core with a real-time air monitoring instrument (e.g., FID, PID, etc.). Carefully separate the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.
2. Collect the volatile sample from the center of the core where elevated readings occurred. If no elevated readings were encountered the sample material should still be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact). Refer to Section 5.2.1 of this procedure.
3. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl. Thoroughly homogenize the sample material prior to filling the remaining sample containers. Refer to Section 5.2.2 of this procedure.
4. Follow steps 4 and 5 listed under Section 5.3 of this procedure.

5.7 Subsurface Sol Sampling Using Direct Push Technology

Subsurface soil samples can be collected to depths of 40+ feet using direct push technology (DPT). DPT equipment, responsibilities, and procedures are described in SOP SA-2.5.

5.8 Excavation and Sampling of Test Pits and Trenches

5.8.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise which control the method of excavation. No personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart P - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is still required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden or steel support structures. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments. Any entry may constitute a Confined Space and must be done in conformance with all applicable regulations. In these cases, substantial air monitoring is required before entry, and appropriate respiratory gear and protective clothing is mandatory. There must be at least two persons present at the immediate site before entry by one of the investigators. The reader shall refer to OSHA regulations 29 CFR 1926, 29 CFR 1910.120, 29 CFR 1910.134, AND 29 CFR 1910.146.

Excavations are generally not practical where a depth of more than about 15 feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If data on soils at depths greater than 15 feet are required, the data are usually obtained through test borings instead of test pits.

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In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

5.8.2 Test Pit and Trench Excavation

These procedures describe the methods for excavating and logging test pits and trenches excavated to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented as described in SOP SA-6.3.

Test pits and trenches may be excavated by hand or by power equipment to permit detailed description of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration.
- The space required for efficient excavation.
- The chemicals of concern.
- The economics and efficiency of available equipment.

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table, which is based on equipment efficiencies, gives a rough guide for design consideration:

Equipment	Typical Widths, in Feet
Trenching machine	2
Backhoe	2-6
Track dozer	10
Track loader	10
Excavator	10
Scraper	20

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous waste materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, field conditions may necessitate revisions to the initial plans. The final depth and construction method shall be determined by the field geologist. The actual layout of each test pit, temporary staging area, and spoils pile will be predicated based on site conditions and wind direction at the time the test pit is made. Prior to excavation, the area can be surveyed by magnetometer or metal detector to identify the presence of underground utilities or drums.

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As mentioned previously, no personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is still required, Occupational Safety and Health Administration (OSHA) requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be in the hole at all times, and a temporary guardrail must be placed along the surface of the hole before entry). It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example, samples of leachate, groundwater, or sidewall soils can be taken with telescoping poles, etc.

Dewatering may be required to assure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation dry. This is an important consideration for excavations in cohesionless material below the groundwater table. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

5.8.3 Sampling in Test Pits and Trenches

5.8.3.1 General

Test pits and trenches are usually logged as they are excavated. Records of each test pit/trench will be made as described in SOP SA-6.3. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable Health and Safety and OSHA requirements have been met.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information would include soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples, which can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

5.8.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks and hand augers, stainless steel trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottleware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.

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- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps and right angle adapter for conduit (see Attachment B).

5.8.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 5.7.3.4.

- Excavate trench or pit in several depth increments. After each increment, the operator will wait while the sampler inspects the test pit from grade level to decide if conditions are appropriate for sampling. (Monitoring of volatiles by the SSO will also be used to evaluate the need for sampling.) Practical depth increments range from 2 to 4 feet.
- The backhoe operator, who will have the best view of the test pit, will immediately cease digging if:
- Any fluid phase or groundwater seepage is encountered in the test pit.
- Any drums, other potential waste containers, obstructions or utility lines are encountered.
- Distinct changes of material are encountered.

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending upon the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Remove loose material to the greatest extent possible with backhoe.
- Secure walls of pit if necessary. (There is seldom any need to enter a pit or trench which would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)
- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material once it has been deposited on the ground. The sampler or Field Operations Leader directs the backhoe operator to remove material from the selected depth or location within the test pit/trench. The bucket is brought to the surface and moved away from the pit. The sampler and/or SSO then approaches the bucket and monitors its contents with a photolionization or flame ionization detector. The sample is collected from the center of the bucket or pile and placed in sample containers using a decontaminated stainless steel trowel or spatula.
- If a composite sample is desired, several depths or locations within the pit/trench are selected and a bucket is filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.
- Using the remote sampler shown in Attachment B, samples can be taken at the desired depth from the side wall or bottom of the pit. The face of the pit/trench shall first be scraped (using a long-

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handled shovel or hoe) to remove the smeared zone that has contacted the backhoe bucket. The sample shall then be collected directly into the sample jar, by scraping with the jar edge, eliminating the need to utilize samplers and minimizing the likelihood of cross-contamination. The sample jar is then capped, removed from the assembly, and packaged for shipment.

- Complete documentation as described in SOP SA-6.3.

5.8.3.4 In-Pit Sampling

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soils or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There is no practical alternative means of obtaining such data.
- The Site Safety Officer and Competent Person determines that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of volatile organics, explosive gases and available oxygen).
- A Company-designated Competent Person determines that the pit/trench is stable or is made stable (by grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements must be strictly observed.

If these conditions are satisfied, one person will enter the pit/trench. On potentially hazardous waste sites, this individual will be dressed in safety gear as required by the conditions in the pit, usually Level B. He/she will be affixed to a safety rope and continuously monitored while in the pit.

A second individual will be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations. The individual entering the pit will remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon. As an added precaution, it is advisable to keep the backhoe bucket in the test pit when personnel are working below grade. Such personnel can either stand in or near the bucket while performing sample operations. In the event of a cave-in they can either be lifted clear in the bucket, or at least climb up on the backhoe arm to reach safety.

5.8.3.5 Geotechnical Sampling

In addition to the equipment described in Section 5.7.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., open tube samplers), which can be pushed or driven into the floor of the test pit.

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- Suitable driving (i.e., a sledge hammer) or pushing (i.e., the backhoe bucket) equipment which is used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soils in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification, while larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soils using open tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe, rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the sampler when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 5.7.3.4 of this procedure must be followed. The open tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate, because the sample will not have the correct orientation.

A sledge hammer or the backhoe may be used to drive or push the sampler or tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry of the test pit, the requirements in Section 5.7.3.4 of this procedure must be followed. Prepare, label, pack and transport the sample in the required manner, as described in SOP SA-6.3.

5.8.4 Backfilling of Trenches and Test Pits

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non-working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew shall photograph all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL.

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If a low permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

5.9 Records

The appropriate sample log sheet (see SOP SA-6.3; Field Documentation) must be completed by the site geologist/sampler. All soil sampling locations must be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) and shall be noted on the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see SOP SA-6.3; Field Documentation) shall contain a sketch of pit conditions. In addition, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.

Other data to be recorded in the field logbook include the following:

- Name and location of job.
- Date of boring and excavation.
- Approximate surface elevation.
- Total depth of boring and excavation.
- Dimensions of pit.
- Method of sample acquisition.
- Type and size of samples.
- Soil and rock descriptions.
- Photographs.
- Groundwater levels.
- Organic gas or methane levels.
- Other pertinent information, such as waste material encountered.

6.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

NUS Corporation, 1986. Hazardous Material Handling Training Manual.

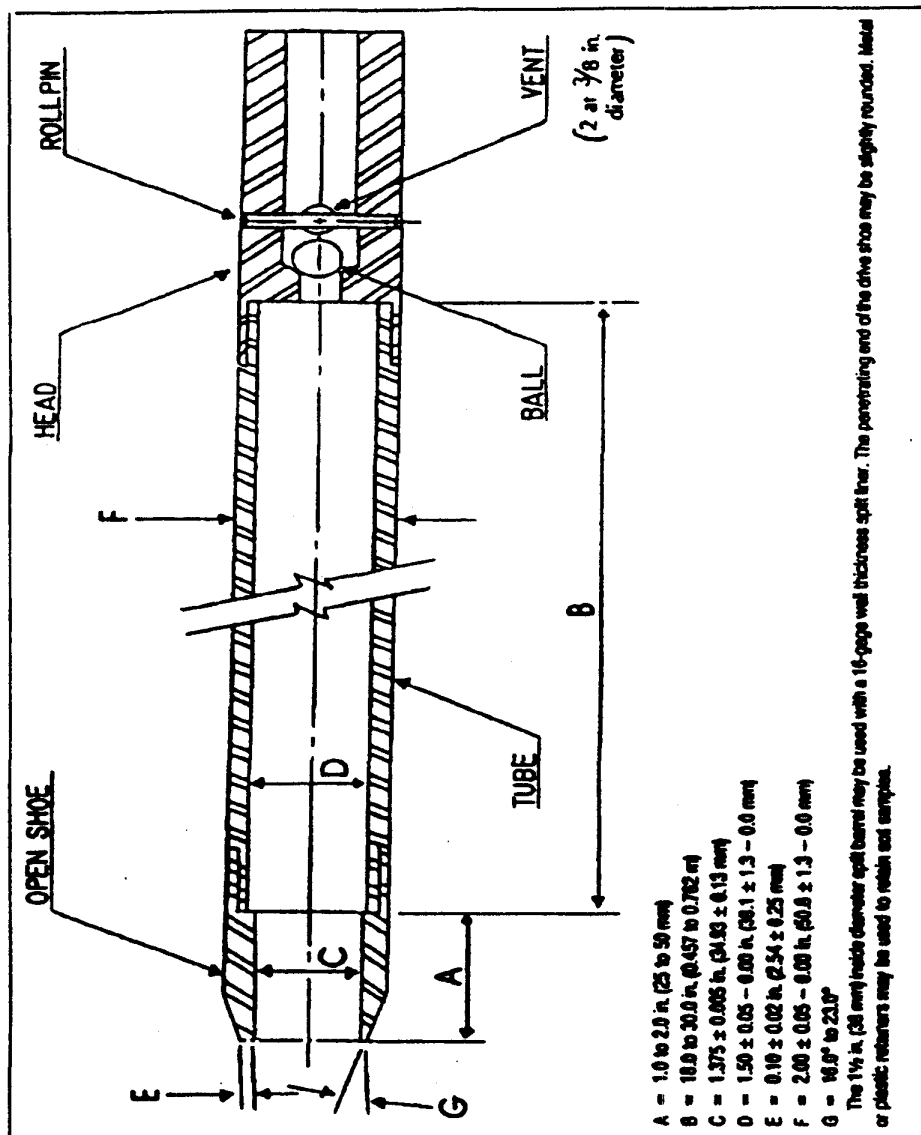
NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

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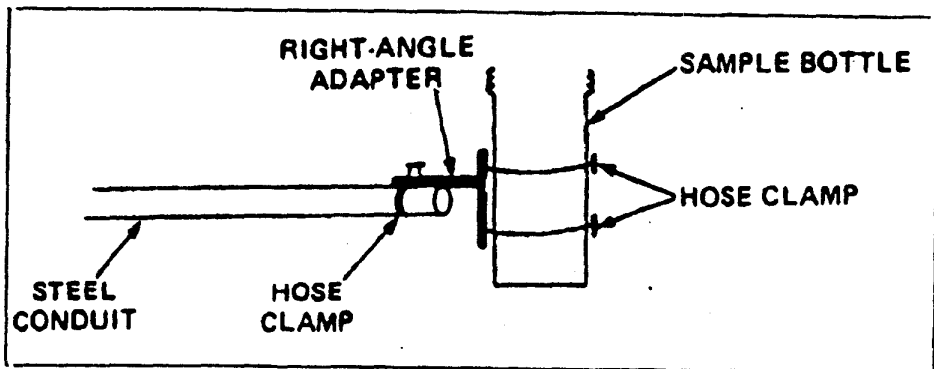
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ATTACHMENT A
SPLIT-SPOON SAMPLER



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ATTACHMENT B
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING





TETRA TECH NUS, INC.

STANDARD OPERATING PROCEDURES

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Effective Date	01/00	Revision	1
Applicability	Tetra Tech NUS, Inc.		
Prepared	Earth Sciences Department		
Approved	D. Senovich <i>DS</i>		

Subject
FIELD DOCUMENTATION

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1.0 PURPOSE

The purpose of this Standard Operating Procedure (SOP) is to identify and designate the field data record forms, logs and reports generally initiated and maintained for documenting Tetra Tech NUS field activities.

2.0 SCOPE

Documents presented within this procedure (or equivalents) shall be used for all Tetra Tech NUS field activities, as applicable. Other or additional documents may be required by specific client contracts or project planning documents.

3.0 GLOSSARY

None

4.0 RESPONSIBILITIES

Project Manager (PM) - The Project Manager is responsible for obtaining hardbound, controlled-distribution logbooks (from the appropriate source), as needed. In addition, the Project Manager is responsible for placing all field documentation used in site activities (i.e., records, field reports, sample data sheets, field notebooks, and the site logbook) in the project's central file upon the completion of field work.

Field Operations Leader (FOL) - The Field Operations Leader is responsible for ensuring that the site logbook, notebooks, and all appropriate and current forms and field reports illustrated in this guideline (and any additional forms required by the contract) are correctly used, accurately filled out, and completed in the required time-frame.

5.0 PROCEDURES

5.1 Site Logbook

5.1.1 General

The site logbook is a hard-bound, paginated, controlled-distribution record book in which all major onsite activities are documented. At a minimum, the following activities/events shall be recorded or referenced (daily) in the site logbook:

- All field personnel present
- Arrival/departure of site visitors
- Arrival/departure of equipment
- Start and/or completion of borehole, trench, monitoring well installation, etc.
- Daily onsite activities performed each day
- Sample pickup information
- Health and Safety issues (level of protection observed, etc.)
- Weather conditions

A site logbook shall be maintained for each project. The site logbook shall be initiated at the start of the first onsite activity (e.g., site visit or initial reconnaissance survey). Entries are to be made for every day that onsite activities take place which involve Tetra Tech NUS or subcontractor personnel. Upon completion of the fieldwork, the site logbook must become part of the project's central file.

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The following information must be recorded on the cover of each site logbook:

- Project name
- Tetra Tech NUS project number
- Sequential book number
- Start date
- End date

Information recorded daily in the site logbook need not be duplicated in other field notebooks (see Section 5.2), but must summarize the contents of these other notebooks and refer to specific page locations in these notebooks for detailed information (where applicable). An example of a typical site logbook entry is shown in Attachment A.

If measurements are made at any location, the measurements and equipment used must either be recorded in the site logbook or reference must be made to the field notebook in which the measurements are recorded (see Attachment A).

All logbook, notebook, and log sheet entries shall be made in indelible ink (black pen is preferred). No erasures are permitted. If an incorrect entry is made, the data shall be crossed out with a single strike mark, and initialed and dated. At the completion of entries by any individual, the logbook pages used must be signed and dated. The site logbook must also be signed by the Field Operations Leader at the end of each day.

5.1.2 Photographs

When movies, slides, or photographs are taken of a site or any monitoring location, they must be numbered sequentially to correspond to logbook/notebook entries. The name of the photographer, date, time, site location, site description, and weather conditions must be entered in the logbook/notebook as the photographs are taken. A series entry may be used for rapid-sequence photographs. The photographer is not required to record the aperture settings and shutter speeds for photographs taken within the normal automatic exposure range. However, special lenses, films, filters, and other image-enhancement techniques must be noted in the logbook/notebook. If possible, such techniques shall be avoided, since they can adversely affect the accuracy of photographs. Chain-of-custody procedures depend upon the subject matter, type of film, and the processing it requires. Film used for aerial photography, confidential information, or criminal investigation require chain-of-custody procedures. Once processed, the slides of photographic prints shall be consecutively numbered and labeled according to the logbook/notebook descriptions. The site photographs and associated negatives must be docketed into the project's central file.

5.2 Field Notebooks

Key field team personnel may maintain a separate dedicated field notebook to document the pertinent field activities conducted directly under their supervision. For example, on large projects with multiple investigative sites and varying operating conditions, the Health and Safety Officer may elect to maintain a separate field notebook. Where several drill rigs are in operation simultaneously, each site geologist assigned to oversee a rig must maintain a field notebook.

5.3 Sample Forms

A summary of the forms illustrated in this procedure is shown as the listing of Attachments in the Table of Contents for this SOP. Forms may be altered or revised for project-specific needs contingent upon client

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approval. Care must be taken to ensure that all essential information can be documented. Guidelines for completing these forms can be found in the related sampling SOP.

5.3.1 Sample Collection, Labeling, Shipment, Request for Analysis, and Field Test Results

5.3.1.1 Sample Log Sheet

Sample Log Sheets are used to record specified types of data while sampling. Attachments B-1 to B-4 are examples of Sample Log Sheets. The data recorded on these sheets are useful in describing the waste source and sample as well as pointing out any problems, difficulties, or irregularities encountered during sampling. A log sheet must be completed for each sample obtained, including field quality control (QC) samples.

5.3.1.2 Sample Label

A typical sample label is illustrated in Attachment B-5. Adhesive labels must be completed and applied to every sample container. Sample labels can usually be obtained from the appropriate Program source electronically generated in-house, or are supplied from the laboratory subcontractor.

5.3.1.3 Chain-of-Custody Record Form

The Chain-of-Custody (COC) Record is a multi-part form that is initiated as samples are acquired and accompanies a sample (or group of samples) as they are transferred from person to person. This form must be used for any samples collected for chemical or geotechnical analysis whether the analyses are performed on site or off site. One carbonless copy of the completed COC form is retained by the field crew, one copy is sent to the Project Manager, while the original is sent to the laboratory. The original (top, signed copy) of the COC form shall be placed inside a large Ziploc-type bag and taped inside the lid of the shipping cooler. If multiple coolers are sent but are included on one COC form, the COC form should be sent with the first cooler. The COC form should then state how many coolers are included with that shipment. An example of a Chain-of-Custody Record form is provided as Attachment B-6. Once the samples are received at the laboratory, the sample cooler and contents are checked and any problems are noted on the enclosed COC form (any discrepancies between the sample labels and COC form and any other problems that are noted are resolved through communication between the laboratory point-of-contact and the Tetra Tech NUS Project Manager). The COC form is signed and copied. The laboratory will retain the copy while the original becomes part of the samples' corresponding analytical data package.

5.3.1.4 Chain-of-Custody Seal

Attachment B-7 is an example of a custody seal. The Custody seal is an adhesive-backed label. It is part of a chain-of-custody process and is used to prevent tampering with samples after they have been collected in the field and sealed in coolers for transport to the laboratory. The COC seals are signed and dated by the samplers and affixed across the opening edges of each cooler containing environmental samples. COC seals may be available from the laboratory; these seals may also be purchased from a supplier.

5.3.1.5 Field Analytical Log Sheets for Geochemical Parameters

Field Analytical Log Sheets (Attachment B-8) are used to record geochemical and/or natural attenuation field test results. Attachments B-8 (3-page form) should be used when applicable.

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5.3.2 Hydrogeological and Geotechnical Forms

5.3.2.1 Groundwater Level Measurement Sheet

A groundwater level measurement sheet, shown in Attachment C-1 must be filled out for each round of water level measurements made at a site.

5.3.2.2 Data Sheet for Pumping Test

During the performance of a pumping test (or an in-situ hydraulic conductivity test), a large amount of data must be recorded, often within a short time period. The pumping test data sheet (Attachment C-2) facilitates this task by standardizing the data collection format, and allowing the time interval for collection to be laid out in advance.

5.3.2.3 Packer Test Report Form

A packer test report form shown in Attachment C-3 must be completed for each well upon which a packer test is conducted.

5.3.2.4 Summary Log of Boring

During the progress of each boring, a log of the materials encountered, operation and driving of casing, and location of samples must be kept. The Summary Log of Boring, or Boring Log, (Attachment C-4) is used for this purpose and must be completed for each soil boring performed. In addition, if volatile organics are monitored on cores, samples, cuttings from the borehole, or breathing zone, (using a PID or FID), these results must be entered on the boring log at the appropriate depth. The "Remarks" column can be used to subsequently enter the laboratory sample number, the concentration of key analytical results, or other pertinent information. This feature allows direct comparison of contaminant concentrations with soil characteristics.

5.3.2.5 Monitoring Well Construction Details Form

A Monitoring Well Construction Details Form must be completed for every monitoring well, piezometer, or temporary well point installed. This form contains specific information on length and type of well riser pipe and screen, backfill, filter pack, annular seal and grout characteristics, and surface seal characteristics. This information is important in evaluating the performance of the monitoring well, particularly in areas where water levels show temporal variation, or where there are multiple (immiscible) phases of contaminants. Depending on the type of monitoring well (in overburden or bedrock), different forms are used (see Attachments C-5 through C-9). Similar forms are used for flush-mount well completions.

5.3.2.6 Test Pit Log

When a test pit or trench is constructed for investigative or sampling purposes, a Test Pit Log (Attachment C-10) must be filled out by the responsible field geologist or sampling technician.

5.3.2.7 Miscellaneous Monitoring Well Forms

Monitoring Well Materials Certificate of Conformance (Attachment C-11) should be used as the project directs to document all materials utilized during each monitoring well installation.

The Monitoring Well Development Record (Attachment C-12) should be used as the project directs to document all well development activities.

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5.3.3 Equipment Calibration and Maintenance Form

The calibration or standardization of monitoring, measuring or test equipment is necessary to assure the proper operation and response of the equipment, to document the accuracy, precision or sensitivity of the measurement, and determine if correction should be applied to the readings. Some items of equipment require frequent calibration, others infrequent. Some are calibrated by the manufacturer, others by the user.

Each instrument requiring calibration has its own Equipment Calibration Log (Attachment D) which documents that the manufacturer's instructions were followed for calibration of the equipment, including frequency and type of standard or calibration device. An Equipment Calibration Log must be maintained for each electronic measuring device used in the field; entries must be made for each day the equipment is used.

5.4 Field Reports

The primary means of recording onsite activities is the site logbook. Other field notebooks may also be maintained. These logbooks and notebooks (and supporting forms) contain detailed information required for data interpretation or documentation, but are not easily useful for tracking and reporting of progress. Furthermore, the field logbook/notebooks remain onsite for extended periods of time and are thus not accessible for timely review by project management.

5.4.1 Daily Activities Report

To provide timely oversight of onsite contractors, Daily Activities Reports are completed and submitted as described below.

5.4.1.1 Description

The Daily Activities Report (DAR) documents the activities and progress for each day's field work. This report must be filled out on a daily basis whenever there are drilling, test pitting, well construction, or other related activities occurring which involve subcontractor personnel. These sheets summarize the work performed and form the basis of payment to subcontractors (Attachment E is an example of a Daily Activities Report).

5.4.1.2 Responsibilities

It is the responsibility of the rig geologist to complete the DAR and obtain the driller's signature acknowledging that the times and quantities of material entered are correct.

5.4.1.3 Submittal and Approval

At the end of the shift, the rig geologist must submit the Daily Activities Report to the Field Operations Leader (FOL) for review and filing. The Daily Activities Report is not a formal report and thus requires no further approval. The DAR reports are retained by the FOL for use in preparing the site logbook and in preparing weekly status reports for submission to the Project Manager.

5.4.2 Weekly Status Reports

To facilitate timely review by project management, photocopies of logbook/notebook entries may be made for internal use.

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It should be noted that in addition to the summaries described herein, other summary reports may also be contractually required. Attachment F is an example of a Field Trip Summary Report form.

6.0 ATTACHMENTS

Attachment A	TYPICAL SITE LOGBOOK ENTRY
Attachment B-1	EXAMPLE GROUNDWATER SAMPLE LOG SHEET
Attachment B-2	EXAMPLE SURFACE WATER SAMPLE LOG SHEET
Attachment B-3	EXAMPLE SOIL/SEDIMENT SAMPLE LOG SHEET
Attachment B-4	CONTAINER SAMPLE LOG SHEET FORM
Attachment B-5	SAMPLE LABEL
Attachment B-6	CHAIN-OF-CUSTODY RECORD FORM
Attachment B-7	CHAIN-OF-CUSTODY SEAL
Attachment B-8	FIELD ANALYTICAL LOG SHEET
Attachment C-1	EXAMPLE GROUNDWATER LEVEL MEASUREMENT SHEET
Attachment C-2	EXAMPLE PUMPING TEST DATA SHEET
Attachment C-3	PACKER TEST REPORT FORM
Attachment C-4	EXAMPLE BORING LOG
Attachment C-5	EXAMPLE OVERBURDEN MONITORING WELL SHEET
Attachment C-5A	EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)
Attachment C-6	EXAMPLE CONFINING LAYER MONITORING WELL SHEET
Attachment C-7	EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL
Attachment C-8	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK
Attachment C-9	EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK (FLUSHMOUNT)
Attachment C-10	EXAMPLE TEST PIT LOG
Attachment C-11	MONITORING WELL MATERIALS CERTIFICATE OF CONFORMANCE
Attachment C-12	MONITORING WELL DEVELOPMENT RECORD
Attachment D	EXAMPLE EQUIPMENT CALIBRATION LOG
Attachment E	EXAMPLE DAILY ACTIVITIES RECORD
Attachment F	FIELD TRIP SUMMARY REPORT

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**ATTACHMENT A
TYPICAL SITE LOGBOOK ENTRY**

START TIME: _____ DATE: _____

SITE LEADER: _____

PERSONNEL: _____

TINUS

DRILLER

SITE VISITORS

_____	_____	_____
_____	_____	_____
_____	_____	_____

WEATHER: Clear, 68° F, 2-5 mph wind from SE

ACTIVITIES:

1. Steam jenney and fire hoses were set up.
2. Drilling activities at well _____ resumes. Rig geologist was _____. See Geologist's Notebook, No. 1, page 29-30, for details of drilling activity. Sample No. 123-21-S4 collected; see sample logbook, page 42. Drilling activities completed at 11:50 and a 4-inch stainless steel well installed. See Geologist's Notebook, No. 1, page 31, and well construction details for well _____.
3. Drilling rig No. 2 steam-cleaned at decontamination pit. Then set up at location of well _____.
4. Well _____ drilled. Rig geologist was _____. See Geologist's Notebook, No. 2, page _____ for details of drilling activities. Sample numbers 123-22-S1, 123-22-S2, and 123-22-S3 collected; see sample logbook, pages 43, 44, and 45.
5. Well _____ was developed. Seven 55-gallon drums were filled in the flushing stage. The well was then pumped using the pitcher pump for 1 hour. At the end of the hour, water pumped from well was "sand free."
6. EPA remedial project manger arrives on site at 14:25 hours.
7. Large dump truck arrives at 14:45 and is steam-cleaned. Backhoe and dump truck set up over test pit _____.
8. Test pit _____ dug with cuttings placed in dump truck. Rig geologist was _____. See Geologist's Notebook, No. 1, page 32, for details of test pit activities. Test pit subsequently filled. No samples taken for chemical analysis. Due to shallow groundwater table, filling in of test pit _____ resulted in a very soft and wet area. A mound was developed and the area roped off.
9. Express carrier picked up samples (see Sample Logbook, pages 42 through 45) at 17:50 hours. Site activities terminated at 18:22 hours. All personnel off site, gate locked.

Field Operations Leader

Effective Date
01/00

Page__ of __

☐ High Concentration


1

Collected

Signature(s):


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ATTACHMENT B-4

 Tetra Tech NUS, Inc.		Page _____ of _____																					
Project Site Name: _____ Project Number: _____ Site Identification: _____ Container Number(s): _____ Sample Type: <input type="checkbox"/> Grab <input type="checkbox"/> Composite		Sample ID No. _____ Sampled By: _____ C.O.C. No. _____ Concentration: <input type="checkbox"/> High <input type="checkbox"/> Medium <input type="checkbox"/> Low																					
CONTAINER SOURCE		CONTAINER DESCRIPTION																					
DRUM: <input type="checkbox"/> Bung Top <input type="checkbox"/> Lever Lock <input type="checkbox"/> Bolted Ring <input type="checkbox"/> Other _____		COLOR: _____ CONDITION: _____ MARKINGS: _____ VOL OF CONTENTS: _____ OTHER: _____																					
TANK: <input type="checkbox"/> Plastic <input type="checkbox"/> Metal <input type="checkbox"/> Other _____																							
OTHER: _____																							
CONTAINER DISPOSITION		CONTENTS DESCRIPTION																					
SAMPLED: _____ OPENED BUT NOT SAMPLED: Reason _____ NOT OPENED: Reason _____		SINGLE PHASED: _____ MULTIPHASE : <table border="0"> <tr> <td></td> <td align="center">Layer 1</td> <td align="center">Layer 2</td> <td align="center">Layer 3</td> </tr> <tr> <td>Phase (Sol. or Liq.)</td> <td align="center">_____</td> <td align="center">_____</td> <td align="center">_____</td> </tr> <tr> <td>Color</td> <td align="center">_____</td> <td align="center">_____</td> <td align="center">_____</td> </tr> <tr> <td>Viscosity</td> <td align="center">L, M or H</td> <td align="center">L, M or H</td> <td align="center">L, M or H</td> </tr> <tr> <td>% of Total Volume</td> <td align="center">_____</td> <td align="center">_____</td> <td align="center">_____</td> </tr> </table>			Layer 1	Layer 2	Layer 3	Phase (Sol. or Liq.)	_____	_____	_____	Color	_____	_____	_____	Viscosity	L, M or H	L, M or H	L, M or H	% of Total Volume	_____	_____	_____
	Layer 1	Layer 2	Layer 3																				
Phase (Sol. or Liq.)	_____	_____	_____																				
Color	_____	_____	_____																				
Viscosity	L, M or H	L, M or H	L, M or H																				
% of Total Volume	_____	_____	_____																				
MONITOR READING:		SAMPLE and /or INSPECTION DATE & TIME:																					
		_____ HRS.																					
		METHOD: _____																					
SAMPLER(S) and /or INSPECTOR(S) SIGNATURE:		ANALYSIS:																					

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ATTACHMENT B-5

 Tetra Tech NUS, Inc. 661 Andersen Drive Pittsburgh, 15220 (412)921-7090		Project:	
		Site:	
		Location:	
Sample No:			Matrix:
Date:	Time:	Preserve:	
Analysis:			
Sampled by:		Laboratory:	



TETRA TECH NUS, INC.

CHAIN OF CUSTODY

| NUMBER

| PAGE ____ OF ____

PROJECT NO:		SITE NAME:		PROJECT MANAGER AND PHONE NUMBER			LABORATORY NAME AND CONTACT:		
SAMPLERS (SIGNATURE)				FIELD OPERATIONS LEADER AND PHONE NUMBER			ADDRESS		
				CARRIER/WAYBILL NUMBER			CITY, STATE		
STANDARD TAT <input type="checkbox"/> RUSH TAT <input type="checkbox"/> <input type="checkbox"/> 24 hr. <input type="checkbox"/> 48 hr. <input type="checkbox"/> 72 hr. <input type="checkbox"/> 7 day <input type="checkbox"/> 14 day				MATRIX	GRAS (G) COMP (C)	No. OF CONTAINERS	CONTAINER TYPE PLASTIC (P) or GLASS (G)		
PRESERVATIVE USED									
DATE YEAR	TIME	SAMPLE ID		TYPE OF ANALYSIS					
1. RELINQUISHED BY		DATE	TIME						
2. RELINQUISHED BY		DATE	TIME	2 RECEIVED BY			DATE	TIME	
3. RELINQUISHED BY		DATE	TIME	3 RECEIVED BY			DATE	TIME	
COMMENTS									

DISTRIBUTION: WHITE (ACCOMPANIES SAMPLE)

YELLOW (FIELD COPY)

PINK (FILE COPY)

3/99
FORM NO. TINUS-001

Subject

FIELD DOCUMENTATION

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ATTACHMENT B-6

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ATTACHMENT B-7

CHAIN-OF-CUSTODY SEAL

Signature <hr/>		CUSTODY SEAL
Date <hr/>		Date <hr/>
CUSTODY SEAL		Signature <hr/>

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ATTACHMENT B-8



**FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS**

Tetra Tech NUS, Inc.

Page ___ of ___

Project Site Name: _____	Sample ID No.: _____
Project No.: _____	Sample Location: _____
Sampled By: _____	Duplicate: <input type="checkbox"/>
Field Analyst: _____	Blank: <input type="checkbox"/>
Field Form Checked as per QA/QC Checklist (Initials): _____	

Date:	Color (Visual)	pH (S.U.)	S.C. (mS/cm)	Temp. (°C)	Turbidity (NTU)	DO (mg/l)	Salinity (‰)	Other
Time: _____	_____	_____	_____	_____	_____	_____	_____	_____
Method: _____								

SAMPLE COLLECTION/ANALYSIS INFORMATION:

ORP (Eh) (+/- mV): _____ Electrode Make & Model: _____
 Reference Electrode (circle one): Silver-Silver Chloride / Calomel / Hydrogen

Dissolved Oxygen:

Equipment: HACH Digital Titrator OX-DT CHEMetrics (Range: _____ mg/L) Analysis Time: _____

Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration
<input type="checkbox"/>	1-6 mg/L	200 ml	0.200 N	0.01	_____	x 0.01	= _____ mg/L
<input type="checkbox"/>	2-10 mg/L	100 ml	0.200 N	0.02	_____	x 0.02	= _____ mg/L

CHEMetrics: _____ mg/L

Notes: _____

Alkalinity:

Equipment: HACH Digital Titrator AL-DT CHEMetrics (Range: _____ mg/L) Analysis Time: _____
 Filtered: ☐

Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration
<input type="checkbox"/>	10-40 mg/L	100 ml	0.1800 N	0.1	_____	x 0.1	= _____ mg/L
<input type="checkbox"/>	40-180 mg/L	25 ml	0.1800 N	0.4	_____	x 0.4	= _____ mg/L
<input type="checkbox"/>	100-400 mg/L	100 ml	1.800 N	1.0	_____	x 1.0	= _____ mg/L
<input type="checkbox"/>	200-800 mg/L	50 ml	1.800 N	2.0	_____	x 2.0	= _____ mg/L
<input type="checkbox"/>	500-2000 mg/L	20 ml	1.800 N	5.0	_____	x 5.0	= _____ mg/L
<input type="checkbox"/>	1000-4000 mg/L	10 ml	1.800 N	10.0	_____	x 10.0	= _____ mg/L

Parameter:	Hydroxide	Carbonate	Bicarbonate
Relationship:	_____	_____	_____

CHEMetrics: _____ mg/L

Notes: _____

Standard Additions: ☐ Titrant Molarity: _____ Digits Required: 1st: _____ 2nd: _____ 3rd: _____

Carbon Dioxide:

Equipment: HACH Digital Titrator CA-DT CHEMetrics (Range: _____ mg/L) Analysis Time: _____

Range Used:	Range	Sample Vol.	Cartridge	Multiplier	Titration Count	Multiplier	Concentration
<input type="checkbox"/>	10-50 mg/L	200 ml	0.3636 N	0.1	_____	x 0.1	= _____ mg/L
<input type="checkbox"/>	20-100 mg/L	100 ml	0.3636 N	0.2	_____	x 0.2	= _____ mg/L
<input type="checkbox"/>	100-400 mg/L	200 ml	3.636 N	1.0	_____	x 1.0	= _____ mg/L
<input type="checkbox"/>	200-1000 mg/L	100 ml	3.636 N	2.0	_____	x 2.0	= _____ mg/L

CHEMetrics: _____ mg/L

Notes: _____

Standard Additions: ☐ Titrant Molarity: _____ Digits Required: 1st: _____ 2nd: _____ 3rd: _____

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ATTACHMENT B-8 (Continued)



FIELD ANALYTICAL LOG SHEET
GEOCHEMICAL PARAMETERS


Tetra Tech NUS, Inc.

Page __ of __

Project Site Name: _____		Sample ID No.: _____	
Project No.: _____		Sample Location: _____	
Sampled By: _____		Duplicate: <input type="checkbox"/>	
Field Analyst: _____		Blank: <input type="checkbox"/>	
Field Form Checked as per QA/QC Checklist (initials): _____			
SAMPLE COLLECTION/ANALYSIS INFORMATION:			
Sulfide (S^{2-}):			
Equipment: DR-700	DR-8 __	HS-WR Color Wheel	Other: _____ Analysis Time: _____
Program/Module: 610nm	93		
Concentration: _____ mg/L		Filtered: <input type="checkbox"/>	
Notes: _____			
Sulfate (SO_4^{2-}):			
Equipment: DR-700	DR-8 __	Other: _____	Analysis Time: _____
Program/Module: 91			
Concentration: _____ mg/L		Filtered: <input type="checkbox"/>	
Standard Solution: <input type="checkbox"/>	Results: _____		
Standard Additions: <input type="checkbox"/>	Digits Required: 0.1ml: _____ 0.2ml: _____ 0.3ml: _____		
Notes: _____			
Nitrite (NO_2^--N):			
Equipment: DR-700	DR-8 __	Other: _____	Analysis Time: _____
Program/Module: 60			
Concentration: _____ mg/L		Filtered: <input type="checkbox"/>	
	Reagent Blank Correction: <input type="checkbox"/>		
Standard Solution: <input type="checkbox"/>	Results: <input type="checkbox"/>		
Notes: _____			
Nitrate (NO_3^--N):			
Equipment: DR-700	DR-8 __	Other: _____	Analysis Time: _____
Program/Module: 55			
Concentration: _____ mg/L		Filtered: <input type="checkbox"/>	
	Nitrite Interference Treatment: <input type="checkbox"/>		
Standard Solution: <input type="checkbox"/>	Results: _____		Reagent Blank Correction: <input type="checkbox"/>
Standard Additions: <input type="checkbox"/>	Digits Required: 0.1ml: _____ 0.2ml: _____ 0.3ml: _____		
Notes: _____			

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ATTACHMENT B-8 (Continued)

		FIELD ANALYTICAL LOG SHEET GEOCHEMICAL PARAMETERS		Page <u> </u> of <u> </u>
Tetra Tech NUS, Inc.				
Project Site Name: _____		Sample ID No.: _____		
Project No.: _____		Sample Location: _____		
Sampled By: _____		Duplicate: <input type="checkbox"/>		
Field Analyst: _____		Blank: <input type="checkbox"/>		
Field Form Checked as per QA/QC Checklist (Initials): _____				
SAMPLE COLLECTION/ANALYSIS INFORMATION:				
Manganese (Mn²⁺):				
Equipment: DR-700	DR-8	HACH MN-5	Other: _____	Analysis Time: _____
Program/Module: 525nm	41			
Concentration: _____ mg/L				Filtered: <input type="checkbox"/>
Standard Solution: <input type="checkbox"/>	Results: _____			Digestion: <input type="checkbox"/>
Standard Additions: <input type="checkbox"/>	Digits Required: 0.1ml: _____ 0.2ml: _____ 0.3ml: _____			Reagent Blank Correction: <input type="checkbox"/>
Notes: _____				
Ferrous Iron (Fe²⁺):				
Equipment: DR-700	DR-8	IR-18C Color Wheel	Other: _____	Analysis Time: _____
Program/Module: 500nm	33			
Concentration: _____ mg/L				Filtered: <input type="checkbox"/>
Notes: _____				
Hydrogen Sulfide (H₂S):				
Equipment: HS-C		Other: _____		Analysis Time: _____
Concentration: _____ mg/L		Exceeded 5.0 mg/L range on color chart: <input type="checkbox"/>		
Notes: _____				
QA/QC Checklist:				
All data fields have been completed as necessary: <input type="checkbox"/>				
Correct measurement units are cited in the SAMPLING DATA block: <input type="checkbox"/>				
Values cited in the SAMPLING DATA block are consistent with the Groundwater Sample Log Sheet: <input type="checkbox"/>				
Multiplication is correct for each Multiplier table: <input type="checkbox"/>				
Final calculated concentration is within the appropriate Range Used block: <input type="checkbox"/>				
Alkalinity Relationship is determined appropriately as per manufacturer (HACH) instructions: <input type="checkbox"/>				
QA/QC sample (e.g., Std. Additions, etc.) frequency is appropriate as per the project planning documents: <input type="checkbox"/>				
Nitrite Interference treatment was used for Nitrate test if Nitrite was detected: <input type="checkbox"/>				
Title block on each page of form is initialized by person who performed this QA/QC Checklist: <input type="checkbox"/>				


01/00

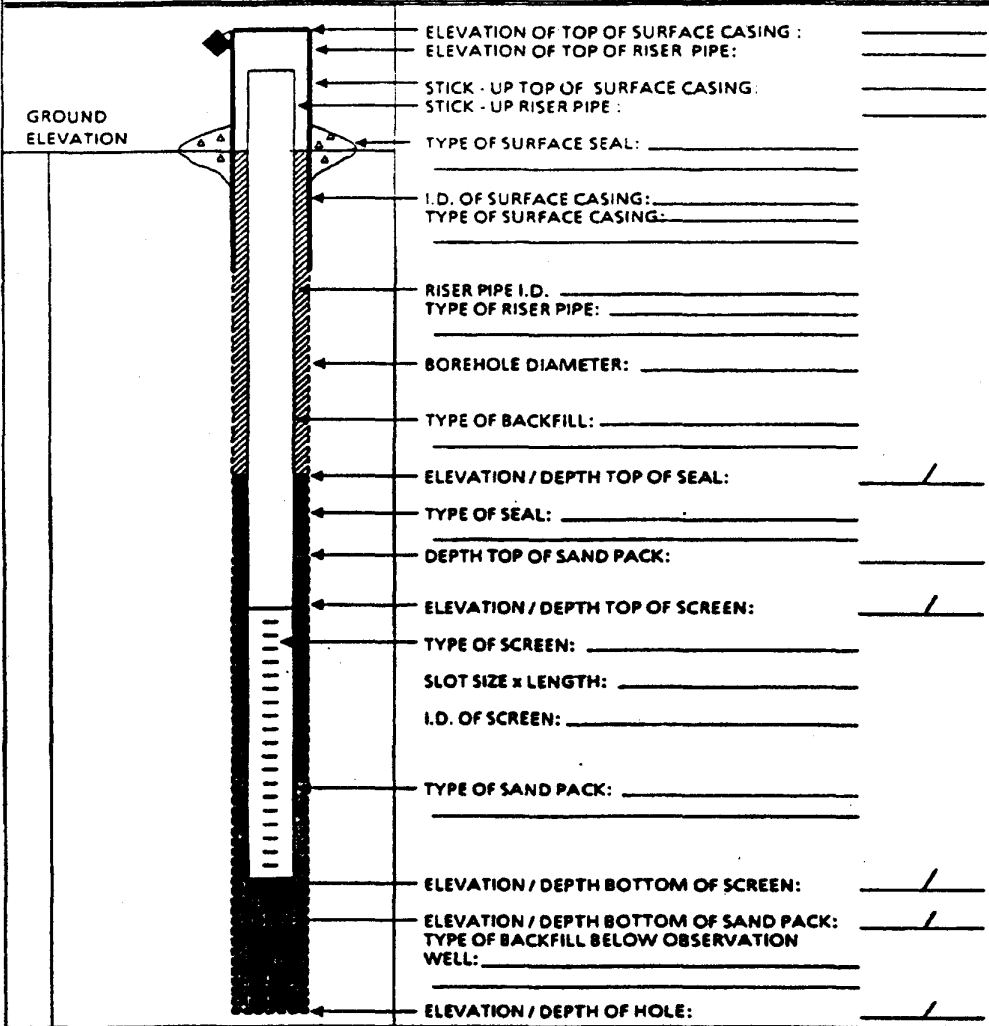
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**ATTACHMENT C-5
EXAMPLE OVERBURDEN MONITORING WELL SHEET**

		BORING NO.: _____	
		OVERBURDEN MONITORING WELL SHEET	
PROJECT _____	LOCATION _____	DRILLER _____	
PROJECT NO. _____	BORING _____	DRILLING _____	
ELEVATION _____	DATE _____	METHOD _____	
FIELD GEOLOGIST _____		DEVELOPMENT _____	
		METHOD _____	



GROUND ELEVATION

ELEVATION OF TOP OF SURFACE CASING: _____

ELEVATION OF TOP OF RISER PIPE: _____

STICK-UP TOP OF SURFACE CASING: _____

STICK-UP RISER PIPE: _____

TYPE OF SURFACE SEAL: _____

I.D. OF SURFACE CASING: _____

TYPE OF SURFACE CASING: _____

RISER PIPE I.D. _____

TYPE OF RISER PIPE: _____

BOREHOLE DIAMETER: _____

TYPE OF BACKFILL: _____

ELEVATION / DEPTH TOP OF SEAL: _____ / _____

TYPE OF SEAL: _____

DEPTH TOP OF SAND PACK: _____

ELEVATION / DEPTH TOP OF SCREEN: _____ / _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

I.D. OF SCREEN: _____

TYPE OF SAND PACK: _____

ELEVATION / DEPTH BOTTOM OF SCREEN: _____ / _____

ELEVATION / DEPTH BOTTOM OF SAND PACK: _____ / _____

TYPE OF BACKFILL BELOW OBSERVATION WELL: _____

ELEVATION / DEPTH OF HOLE: _____ / _____

Subject

FIELD DOCUMENTATION

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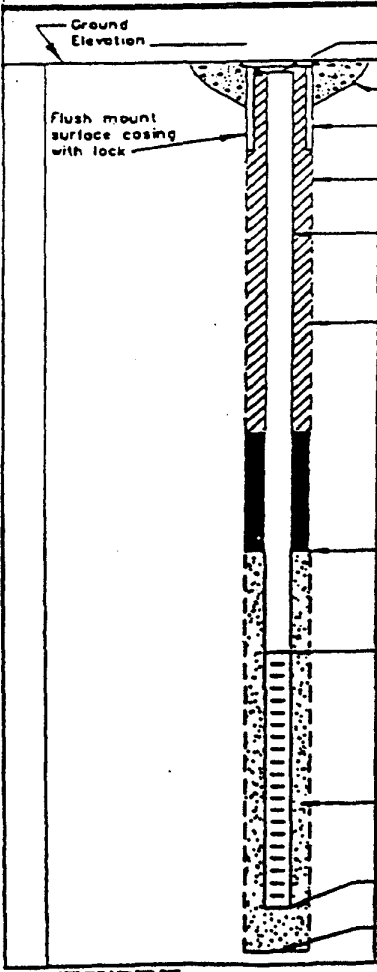
1

Effective Date

01/00

ATTACHMENT C-5A
EXAMPLE OVERBURDEN MONITORING WELL SHEET (FLUSHMOUNT)

 MONITORING WELL SHEET		
BORING NO.: _____		
PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING _____
ELEVATION _____	DATE _____	METHOD _____
FIELD GEOLOGIST _____		DEVELOPMENT _____
		METHOD _____



ELEVATION TOP OF RISER: _____

TYPE OF SURFACE SEAL: _____

TYPE OF PROTECTIVE CASING: _____

I.D. OF PROTECTIVE CASING: _____

DIAMETER OF HOLE: _____

TYPE OF RISER PIPE: _____

RISER PIPE I.D.: _____

TYPE OF BACKFILL/SEAL: _____

DEPTH/ELEVATION TOP OF SAND: _____

DEPTH/ELEVATION TOP OF SCREEN: _____

TYPE OF SCREEN: _____

SLOT SIZE x LENGTH: _____

TYPE OF SAND PACK: _____

DIAMETER OF HOLE IN BEDROCK: _____

DEPTH/ELEVATION BOTTOM OF SCREEN: _____


DEPTH/ELEVATION BOTTOM OF SAND: _____

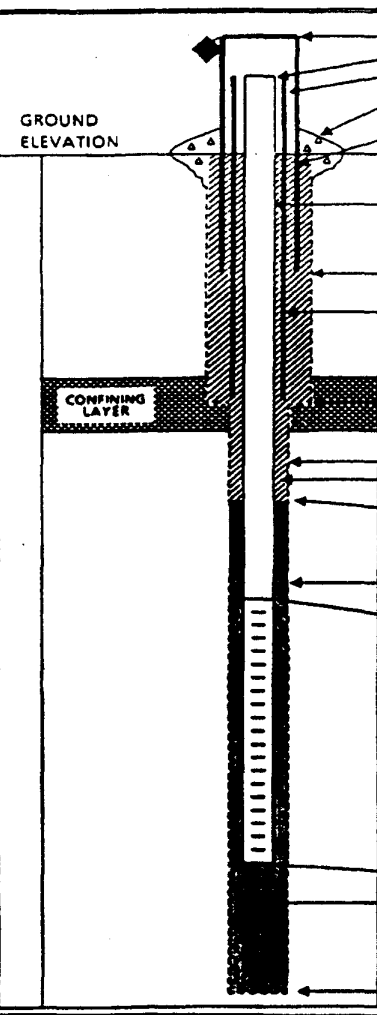
DEPTH/ELEVATION BOTTOM OF HOLE: _____

BACKFILL MATERIAL BELOW SAND: _____

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**ATTACHMENT C-6
EXAMPLE CONFINING LAYER MONITORING WELL SHEET**


		BORING NO.: _____	
		CONFINING LAYER MONITORING WELL SHEET	
PROJECT _____	LOCATION _____	DRILLER _____	
PROJECT NO. _____	BORING _____	DRILLING _____	
ELEVATION _____	DATE _____	METHOD _____	
FIELD GEOLOGIST _____		DEVELOPMENT _____	
		METHOD _____	

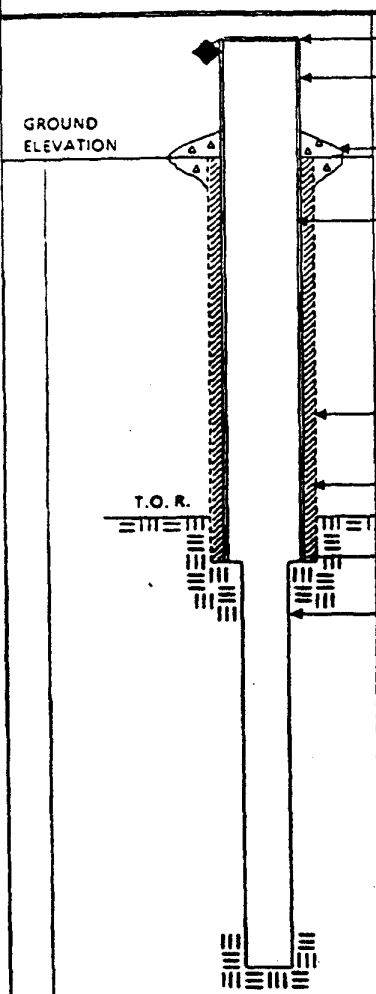


ELEVATION OF TOP OF SURFACE CASING :	_____
ELEVATION OF TOP OF RISER PIPE:	_____
ELEVATION TOP OF PERM. CASING:	_____
TYPE OF SURFACE SEAL:	_____
I.D. OF SURFACE CASING:	_____
TYPE OF SURFACE CASING:	_____
RISER PIPE I.D. _____	
TYPE OF RISER PIPE:	_____
BOREHOLE DIAMETER:	_____
PERM. CASING I.D. _____	
TYPE OF CASING & BACKFILL:	_____
ELEVATION / DEPTH TOP CONFINING LAYER:	_____
ELEVATION / DEPTH BOTTOM OF CASING:	_____
ELEVATION / DEPTH BOT. CONFINING LAYER:	_____
BOREHOLE DIA. BELOW CASING:	_____
TYPE OF BACKFILL:	_____
ELEVATION / DEPTH TOP OF SEAL:	_____
TYPE OF SEAL:	_____
DEPTH TOP OF SAND PACK:	_____
ELEVATION/DEPTH TOP OF SCREEN:	_____
TYPE OF SCREEN:	_____
TYPE OF SAND PACK:	_____
ELEVATION / DEPTH BOTTOM OF SCREEN:	_____
ELEVATION / DEPTH BOTTOM OF SAND PACK:	_____
TYPE OF BACKFILL BELOW OBSERVATION WELL:	_____
ELEVATION / DEPTH OF HOLE:	_____

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ATTACHMENT C-7
EXAMPLE BEDROCK MONITORING WELL SHEET - OPEN HOLE WELL

		BEDROCK MONITORING WELL SHEET OPEN HOLE WELL		BORING NO.: _____
PROJECT _____ PROJECT NO. _____ ELEVATION _____ FIELD GEOLOGIST _____		LOCATION _____ BORING _____ DATE _____		DRILLER _____ DRILLING METHOD _____ DEVELOPMENT METHOD _____

	ELEVATION OF TOP OF CASING:	_____
	STICK UP OF CASING ABOVE GROUND SURFACE:	_____
	TYPE OF SURFACE SEAL:	_____
	I.D. OF CASING:	_____
	TYPE OF CASING:	_____
	TEMP. / PERM.:	_____
	DIAMETER OF HOLE:	_____
	TYPE OF CASING SEAL:	_____
	DEPTH TO TOP OF ROCK:	_____
	DEPTH TO BOTTOM CASING:	_____
DIAMETER OF HOLE IN BEDROCK:	_____	
DESCRIBE IF CORE / REAMED WITH BIT:		_____
DESCRIBE JOINTS IN BEDROCK AND DEPTH:		_____
ELEVATION / DEPTH OF HOLE:		_____ / _____

Subject

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ATTACHMENT C-8
EXAMPLE BEDROCK MONITORING WELL SHEET - WELL INSTALLED IN BEDROCK

BEDROCK MONITORING WELL SHEET WELL INSTALLED IN BEDROCK		BORING NO.:
PROJECT _____	LOCATION _____	DRILLER _____
PROJECT NO. _____	BORING _____	DRILLING METHOD _____
ELEVATION _____	DATE _____	DEVELOPMENT METHOD _____
FIELD GEOLOGIST _____		

	ELEVATION OF TOP OF SURFACE CASING: _____
	STICK UP OF CASING ABOVE GROUND SURFACE: _____
	ELEVATION TOP OF RISER: _____
	TYPE OF SURFACE SEAL: _____
	I.D. OF SURFACE CASING: _____
	DIAMETER OF HOLE: _____
	RISER PIPE I.D.: _____
	TYPE OF RISER PIPE: _____
	TYPE OF BACKFILL: _____
	ELEVATION / DEPTH TOP OF SEAL: _____
	ELEVATION / DEPTH TOP OF BEDROCK: _____
	TYPE OF SEAL: _____
	ELEVATION / DEPTH TOP OF SAND: _____
	ELEVATION / DEPTH TOP OF SCREEN: _____
	TYPE OF SCREEN: _____
SLOT SIZE x LENGTH: _____	
I.D. SCREEN: _____	
TYPE OF SAND PACK: _____	
DIAMETER OF HOLE IN BEDROCK: _____	
CORE / REAM: _____	
ELEVATION / DEPTH BOTTOM SCREEN: _____	
ELEVATION / DEPTH BOTTOM OF HOLE: _____	

Subject

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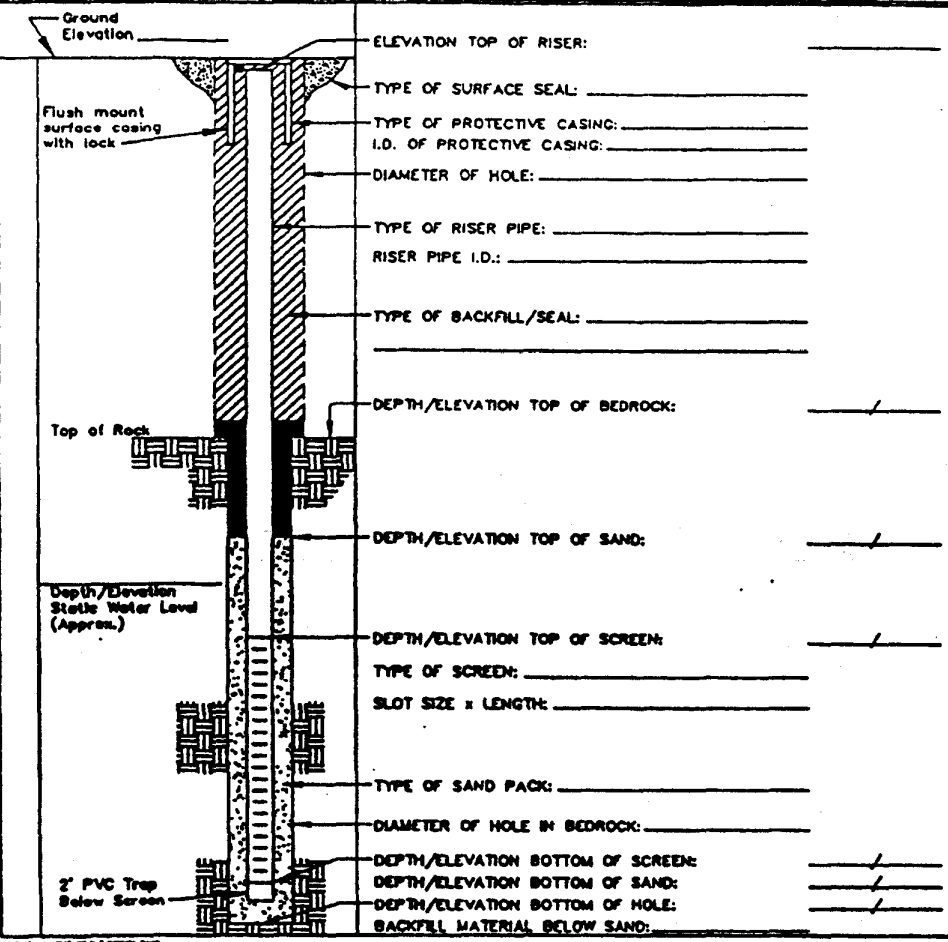
Revision

1

Effective Date

01/00

ATTACHMENT C-9
EXAMPLE BEDROCK MONITORING WELL SHEET
WELL INSTALLED IN BEDROCK (FLUSHMOUNT)

 <div style="display: inline-block; text-align: left; margin-left: 10px;">BEDROCK MONITORING WELL SHEET WELL INSTALLED IN BEDROCK</div>		BORING NO.: _____																																								
<table border="1" style="width: 100%; border-collapse: collapse;"><tr><td style="width: 33%; padding: 2px;">PROJECT: _____</td><td style="width: 33%; padding: 2px;">LOCATION: _____</td><td style="width: 33%; padding: 2px;">DRILLER: _____</td></tr><tr><td style="padding: 2px;">PROJECT NO.: _____</td><td style="padding: 2px;">BORING: _____</td><td style="padding: 2px;">DRILLING METHOD: _____</td></tr><tr><td style="padding: 2px;">ELEVATION: _____</td><td style="padding: 2px;">DATE: _____</td><td style="padding: 2px;">DEVELOPMENT METHOD: _____</td></tr><tr><td colspan="3" style="padding: 2px;">FIELD GEOLOGIST: _____</td></tr></table>			PROJECT: _____	LOCATION: _____	DRILLER: _____	PROJECT NO.: _____	BORING: _____	DRILLING METHOD: _____	ELEVATION: _____	DATE: _____	DEVELOPMENT METHOD: _____	FIELD GEOLOGIST: _____																														
PROJECT: _____	LOCATION: _____	DRILLER: _____																																								
PROJECT NO.: _____	BORING: _____	DRILLING METHOD: _____																																								
ELEVATION: _____	DATE: _____	DEVELOPMENT METHOD: _____																																								
FIELD GEOLOGIST: _____																																										
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ATTACHMENT F
FIELD TRIP SUMMARY REPORT
PAGE 1 OF 2

SUNDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____

Site Activities: _____

MONDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____

Site Activities: _____

TUESDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____

Site Activities: _____

WEDNESDAY

Date: _____ Personnel: _____
Weather: _____ Onsite: _____

Site Activities: _____

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ATTACHMENT F
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FIELD TRIP SUMMARY REPORT

THURSDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

FRIDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

SATURDAY

Date: _____ Personnel: _____

Weather: _____ Onsite: _____

Site Activities: _____

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		Effective Date 03/16/98	Revision 2
		Applicability	
		Prepared Earth Sciences Department	
Subject DECONTAMINATION OF FIELD EQUIPMENT AND WASTE HANDLING		Approved D. Senovich	

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1.0 PURPOSE

The purpose of this procedure is to provide guidelines regarding the appropriate procedures to be followed when decontaminating drilling equipment, monitoring well materials, chemical sampling equipment and field analytical equipment.

2.0 SCOPE

This procedure addresses drilling equipment and monitoring well materials decontamination, as well as chemical sampling and field analytical equipment decontamination. This procedure also provides general reference information on the control of contaminated materials.

3.0 GLOSSARY

Acid - For decontamination of equipment when sampling for trace levels of inorganics, a 10% solution of nitric acid in deionized water should be used. Due to the leaching ability of nitric acid, it should not be used on stainless steel.

Alconox/Liquinox - A brand of phosphate-free laboratory-grade detergent.

Deionized Water - Deionized (analyte free) water is tap water that has been treated by passing through a standard deionizing resin column. Deionized water should contain no detectable heavy metals or other inorganic compounds at or above the analytical detection limits for the project.

Potable Water - Tap water used from any municipal water treatment system. Use of an untreated potable water supply is not an acceptable substitute for tap water.

Solvent - The solvent of choice is pesticide-grade Isopropanol. Use of other solvents (methanol, acetone, pesticide-grade hexane, or petroleum ether) may be required for particular projects or for a particular purpose (e.g. for the removal of concentrated waste) and must be justified in the project planning documents. As an example, it may be necessary to use hexane when analyzing for trace levels of pesticides, PCBs, or fuels. In addition, because many of these solvents are not miscible in water, the equipment should be air dried prior to use. Solvents should not be used on PVC equipment or well construction materials.

4.0 RESPONSIBILITIES

Project Manager - Responsible for ensuring that all field activities are conducted in accordance with approved project plan(s) requirements.

Field Operations Leader (FOL) - Responsible for the onsite verification that all field activities are performed in compliance with approved Standards Operating Procedures or as otherwise dictated by the approved project plan(s).

5.0 PROCEDURES

To ensure that analytical chemical results reflect actual contaminant concentrations present at sampling locations, the various drilling equipment and chemical sampling and analytical equipment used to acquire the environment sample must be properly decontaminated. Decontamination minimizes the potential for cross-contamination between sampling locations, and the transfer of contamination off site.

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5.1 Drilling Equipment

Prior to the initiation of a drilling program, all drilling equipment involved in field sampling activities shall be decontaminated by steam cleaning at a predetermined area. The steam cleaning procedure shall be performed using a high-pressure spray of heated potable water producing a pressurized stream of steam. This steam shall be sprayed directly onto all surfaces of the various equipment which might contact environmental samples. The decontamination procedure shall be performed until all equipment is free of all visible potential contamination (dirt, grease, oil, noticeable odors, etc.) In addition, this decontamination procedure shall be performed at the completion of each sampling and/or drilling location, including soil borings, installation of monitoring wells, test pits, etc. Such equipment shall include drilling rigs, backhoes, downhole tools, augers, well casings, and screens. Where the drilling rig is set to perform multiple borings at a single area of concern, the steam-cleaning of the drilling rig itself may be waived with proper approval. Downhole equipment, however, must always be steam-cleaned between borings. Where PVC well casings are to be installed, decontamination is not required if the manufacturer provides these casings in factory-sealed, protective, plastic sleeves (so long as the protective packaging is not compromised until immediately before use).

The steam cleaning area shall be designed to contain decontamination wastes and waste waters and can be a lined excavated pit or a bermed concrete or asphalt pad. For the latter, a floor drain must be provided which is connected to a holding facility. A shallow above-ground tank may be used or a pumping system with discharge to a waste tank may be installed.

In certain cases such an elaborate decontamination pad is not possible. In such cases, a plastic lined gravel bed pad with a collection system may serve as an adequate decontamination area. Alternately, a lined sloped pad with a collection pump installed at the lower end may be permissible. The location of the steam cleaning area shall be onsite in order to minimize potential impacts at certain sites.

Guidance to be used when decontaminating drilling equipment shall include:

- As a general rule, any part of the drilling rig which extends over the borehole, shall be steam cleaned.
- All drilling rods, augers, and any other equipment which will be introduced to the hole shall be steam cleaned.
- The drilling rig, all rods and augers, and any other potentially contaminated equipment shall be decontaminated between each well location to prevent cross contamination of potential hazardous substances.

Prior to leaving at the end of each work day and/or at the completion of the drilling program, drilling rigs and transport vehicles used onsite for personnel or equipment transfer shall be steam cleaned, as practicable. A drilling rig left at the drilling location does not need to be steam cleaned until it is finished drilling at that location.

5.2 Sampling Equipment

5.2.1 Bailers and Bailing Line

The potential for cross-contamination between sampling points through the use of a common bailer or its attached line is high unless strict procedures for decontamination are followed. For this reason, it is preferable to dedicate an individual bailer and its line to each sample point, although this does not

DECONTAMINATION OF WASTE
EQUIPMENT AND WASTE HANDLING

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eliminate the need for decontamination of dedicated bailers. For non-dedicated sampling equipment, the following conditions and/or decontamination procedures must be followed.

Before the initial sampling and after each successive sampling point, the bailer must be decontaminated. The following steps are to be performed when sampling for organic contaminants. Note: contract-specific requirements may permit alternative procedures.

- Potable water rinse
- Alconox or Liquinox detergent wash
- Scrubbing of the line and bailer with a scrub brush (may be required if the sample point is heavily contaminated with heavy or extremely viscous compounds)
- Potable water rinse
- Rinse with 10 percent nitric acid solution*
- Deionized water rinse
- Pesticide-grade isopropanol (unless otherwise required)
- Pesticide-grade hexane rinse**
- Copious distilled/Deionized water rinse
- Air dry

If sampling for volatile organic compounds (VOCs) only, the nitric acid, isopropanol, and hexane rinses may be omitted. Only reagent grade or purer solvents are to be used for decontamination. When solvents are used, the bailer must be thoroughly dry before using to acquire the next sample.

In general, specially purchased pre-cleaned disposable sampling equipment is not decontaminated (nor is an equipment rinseate blank collected) so long as the supplier has provided certification of cleanliness. If decontamination is performed on several bailers at once (i.e., in batches), bailers not immediately used may be completely wrapped in aluminum foil (shiny-side toward equipment) and stored for future use. When batch decontamination is performed, one equipment rinseate is generally collected from one of the bailers belonging to the batch before it is used for sampling.

It is recommended that clean, dedicated braided nylon or polypropylene line be employed with each bailer use.

5.2.2 Sampling Pumps

Most sampling pumps are low volume (less than 2 gpm) pumps. These include peristaltic, diaphragm, air-lift, pitcher and bladder pumps, to name a few. If these pumps are used for sampling from more than one sampling point, they must be decontaminated prior to initial use and after each use.

The procedures to be used for decontamination of sampling pumps compare to those used for a bailer except that the 10 percent nitric acid solution is omitted. Each of the liquid factions is to be pumped through the system. The amount of pumping is dependent upon the size of the pump and the length of the intake and discharge hoses. Certain types of pumps are unacceptable for sampling purposes. For peristaltic pumps, the tubing is replaced rather than cleaned.

* Due to the leaching ability of nitric acid on stainless steel, this step is to be omitted if a stainless steel sampling device is being used and metals analysis is required with detection limits less than approximately 50 ppb.

** If sampling for pesticides, PCBs, or fuels.

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An additional problem is introduced when the pump relies on absorption of water via an inlet or outlet hose. For organic sampling, this hose should be Teflon. Other types of hoses leach organics (especially phthalate esters) into the water being sampled or adsorb organics from the sampled water. For all other sampling, the hose should be Viton, polyethylene, or polyvinyl chloride (listed in order of preference). Whenever possible, dedicated hoses should be used. It is preferable that these types of pumps not be used for sampling, only for purging.

5.2.3 Filtering Equipment

On occasion, the sampling plan may require acquisition of filtered groundwater samples. Field-filtering is addressed in SOP SA-6.1 and should be conducted as soon after sample acquisition as possible. To this end, three basic filtration systems are most commonly used: the in-line disposable Teflon filter, the inert gas over-pressure filtration system, and the vacuum filtration system.

For the in-line filter, decontamination is not required since the filter cartridge is disposable, however, the cartridge must be disposed of in an approved receptacle and the intake and discharge lines must still be decontaminated or replaced before each use.

For the over-pressure and the vacuum filtration systems, the portions of the apparatus which come in contact with the sample must be decontaminated as outlined in the paragraphs describing the decontamination of bailers. (Note: Varieties of both of these systems come equipped from the manufacturer with Teflon-lined surfaces for those that would come into contact with the sample. These filtration systems are preferred when decontamination procedures must be employed.)

5.2.4 Other Sampling Equipment

Field tools such as trowels and mixing bowls are to be decontaminated in the same manner as described above.

5.3 Field Analytical Equipment

5.3.1 Water Level Indicators

Water level indicators that come into contact with groundwater must be decontaminated using the following steps:

- Rinse with potable water
- Rinse with deionized water

Water level indicators that do not come in contact with the groundwater but may encounter incidental contact during installation or retrieval need only undergo the first and last steps stated above.

5.3.2 Probes

Probes (e.g., pH or specific-ion electrodes, geophysical probes, or thermometers) which would come in direct contact with the sample, will be decontaminated using the procedures specified above unless manufacturer's instructions indicate otherwise (e.g., dissolved oxygen probes). Probes that contact a volume of groundwater not used for laboratory analyses can be rinsed with deionized water. For probes which make no direct contact, (e.g., OVA equipment) the probe is self-cleaning when exposure to uncontaminated air is allowed and the housing can be wiped clean with paper-towels or cloth wetted with alcohol.

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5.4 Waste Handling

For the purposes of these procedures, contaminated materials are defined as any byproducts of field activities that are suspected or known to be contaminated with hazardous substances. These byproducts include such materials as decontamination solutions, disposable equipment, drilling muds, well-development fluids, and spill-contaminated materials and Personal Protection Equipment (PPE).

The procedures for obtaining permits for investigations of sites containing hazardous substances are not clearly defined at present. In the absence of a clear directive to the contrary by the EPA and the states, it must be assumed that hazardous wastes generated during field activities will require compliance with Federal agency requirements for generation, storage, transportation, or disposal. In addition, there may be state regulations that govern the disposal action. This procedure exclusively describes the technical methods used to control contaminated materials.

The plan documents for site activities must include a description of control procedures for contaminated materials. This planning strategy must assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. As a general policy, it is wise to select investigation methods that minimize the generation of contaminated spoils. Handling and disposing of potentially hazardous materials can be dangerous and expensive. Until sample analysis is complete, it is assumed that all produced materials are suspected of contamination from hazardous chemicals and require containment.

5.5 Sources of Contaminated Materials and Containment Methods

5.5.1 Decontamination Solutions

All waste decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site unless there are analytical or other data to the contrary. The waste solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment required cleaning.

Containerized waste rinse solutions are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. Larger equipment such as backhoes and tractors must be decontaminated in an area provided with an impermeable liner and a liquid collection system. A decontamination area for large equipment could consist of a bermed concrete pad with a floor drain leading to a buried holding tank.

5.5.2 Disposable Equipment

Disposable equipment that could become contaminated during use typically includes PPE, rubber gloves, boots, broken sample containers, and cleaning-wipes. These items are small and can easily be contained in 55-gallon drums with lids. These containers should be closed at the end of each work day and upon project completion to provide secure containment until disposed.

5.5.3 Drilling Muds and Well-Development Fluids

Drilling muds and well-development fluids are materials that may be used in groundwater monitoring well installations. Their proper use could result in the surface accumulation of contaminated liquids and muds that require containment. The volumes of drilling muds and well-development fluids used depend on well diameter and depth, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the

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experience of reputable well drillers familiar with local conditions and the well installation techniques selected. These individuals should be able to estimate the sizes (or number) of containment structures required. Since guesswork is involved, it is recommended that an slight excess of the estimated amount of containers required will be available.

Drilling muds are mixed and stored in what is commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling mud is withdrawn and pumped through hoses, down the drill pipe to the bit, and back up the hole to the settling section of the mud pit. In the settling section, the mud's velocity is reduced by a screen and several flow-restriction devices, thereby allowing the well cuttings to settle out of the mud/fluid.

The mud pit may be either portable above-ground tanks commonly made of steel (which is preferred) or stationary in-ground pits as depicted in Attachment A. The above-ground tanks have a major advantage over the in-ground pits because the above-ground tanks isolate the natural soils from the contaminated fluids within the drilling system. These tanks are also portable and can usually be cleaned easily.

As the well is drilled, the cuttings that accumulate in the settling section must be removed. This is best done by shoveling them into drums or other similar containers. When the drilling is complete, the contents of the above-ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and made available for its next use.

If in-ground pits are used, they should not extend into the natural water table. They should also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. Of course, to maintain its impermeable seal, the lining material used would have to be nonreactive with the wastes. An advantage of the in-ground pits is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the above-ground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills, and overflows. In either case, surface drainage should be such that any excess fluid could be controlled within the immediate area of the drill site.

The containment procedure for well-development fluids is similar to that for drilling muds. The volume and weight of contaminated fluid will be determined by the method used for development. When a new well is pumped or bailed to produce clear water, substantially less volume and weight of fluid result than when backwashing or high-velocity jetting is used.

5.5.4 Spill-Contaminated Materials

A spill is always possible when containers of liquids are opened or moved. Contaminated sorbents and soils resulting from spills must be contained. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

5.6 Disposal of Contaminated Materials

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance, that is, incineration, landfilling, treatment, and so on. The problem centers around the

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assignment of responsibility for disposal. The responsibility must be determined and agreed upon by all involved parties before the field work starts. If the site owner or manager was involved in activities that precipitated the investigation, it seems reasonable to encourage his acceptance of the disposal obligation. In instances where a responsible party cannot be identified, this responsibility may fall on the public agency or private organization investigating the site.

Another consideration in selecting disposal methods for contaminated materials is whether the disposal can be incorporated into subsequent site cleanup activities. For example, if construction of a suitable onsite disposal structure is expected, contaminated materials generated during the investigation should be stored at the site for disposal with other site materials. In this case, the initial containment structures should be evaluated for use as long-term storage structures. Also, other site conditions such as drainage control, security, and soil type must be considered so that proper storage is provided. If onsite storage is expected, then the containment structures should be specifically designed for that purpose.

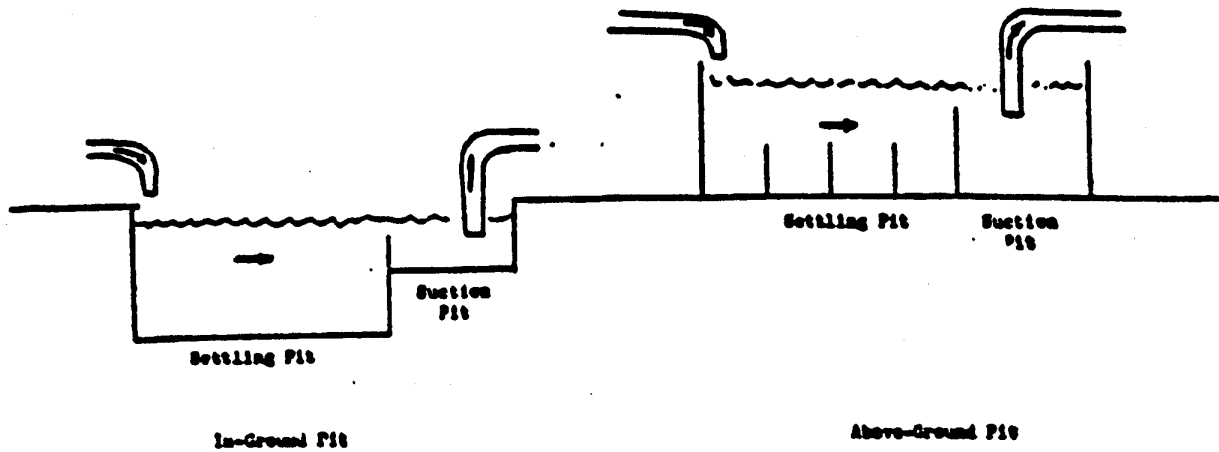
6.0 REFERENCES

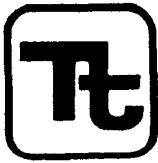
Brown & Root Environmental: Standard Operating Procedure No. 4.33, Control of Contaminated Material.

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ATTACHMENT A

TWO TYPES OF MUD PITS USED IN WELL DRILLING





TETRA TECH NUS, INC.

STANDARD OPERATING PROCEDURES

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Effective Date	01/00	Revision	2
Applicability	Tetra Tech NUS, Inc.		
Prepared	Earth Sciences Department		
Approved	D. Senovich <i>ds</i>		

Subject DIRECT PUSH TECHNOLOGY
(GEOPROBE®/HYDROPUNCH™)

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1.0 PURPOSE

The purpose of this procedure is to provide general reference information on Direct Push Technology (DPT). DPT is designed to collect soil, groundwater, and soil gas samples without using conventional drilling techniques. The advantage of using DPT over conventional drilling includes the generation of little or no drill cuttings, sampling in locations with difficult accessibility, reduced overhead clearance requirements, no fluid introduction during probing, and typical lower costs per sample than with conventional techniques. Disadvantages include a maximum penetration depth of approximately 15 to 40 feet in dense soils (although it may be as much as 60 to 80 feet in certain types of geological environments), reduced capability of obtaining accurate water-level measurements, and the inability to install permanent groundwater monitoring wells. The methods and equipment described herein are for collection of surface and subsurface soil samples and groundwater samples. Soil gas sampling is discussed in SOP SA-2.4.

2.0 SCOPE

This procedure provides information on proper sampling equipment and techniques for DPT. Review of the information contained herein will facilitate planning of the field sampling effort by describing standard sampling techniques. The techniques described shall be followed whenever applicable, noting that site-specific conditions or project-specific plans may require adjustments in methodology.

3.0 GLOSSARY

Direct Push Technology (DPT) - DPT refers to sampling tools and sensors that are driven directly into the ground without the use of conventional drilling equipment. DPT typically utilizes hydraulic pressure and/or percussion hammers to advance the sampling tools. A primary advantage of DPT over conventional drilling techniques is that DPT results in the generation of little or no investigation derived waste.

Geoprobe® - Geoprobe® is a manufacturer of a hydraulically-powered, percussion/probing machines utilizing DPT to collect subsurface environmental samples. Geoprobe® relies on a relatively small amount of static weight (vehicle) combined with percussion as the energy for advancement of a tool string. The Geoprobe® equipment can be mounted in a multitude of vehicles for access to all types of environmental sites.

HydroPunch™ - HydroPunch™ is a manufacturer of stainless steel and Teflon® sampling tools that are capable of collecting representative groundwater and/or soil samples without requiring the installation of a groundwater monitoring well or conventional soil boring. HydroPunch™ is an example of DPT sampling equipment.

Flame Ionization Detector (FID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing a flame as the energizing source.

Photo Ionization Detector (PID) - A portable instrument for the measurement of many combustible organic compounds and a few inorganic compounds in air at parts-per million levels. The basis for the detection is the ionization of gaseous species utilizing ultraviolet radiation as the energizing source.

4.0 RESPONSIBILITIES

Project Manager - The Project Manager is responsible for selecting and/or reviewing the appropriate DPT drilling procedure required to support the project objectives.

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Field Operations Leader (FOL)- The FOL is primarily responsible for performing the DPT in accordance with the project-specific plan.

5.0 SOIL SAMPLING PROCEDURES

5.1 General

The common methodology for the investigation of the vadose zone is soil boring drilling and soil sampling. However, drilling soil borings can be very expensive. Generally the advantage of DPT for subsurface soil sampling is the reduced cost of disposal of drilling cuttings and shorter sampling times.

5.2 Sampling Equipment

Equipment needed for conducting DPT drilling for subsurface soil sampling includes, but is not limited to, the following:

- Geoprobe® Sampling Kit
- Cut-resistant gloves
- 4-foot x 1.5-inch diameter macrocore sampler
- Probe sampling adapters
- Roto-hammer with 1.5-inch bit
- Disposable acetate liners for soil macrocore sampler
- Cast aluminum or steel drive points
- Geoprobe® AT-660 Series Large Bore Soil Sampler, or equivalent
- Standard decontamination equipment and solutions

For health and safety equipment and procedures, follow the direction provided in the Safe Work Permit in Attachment 1, or the more detailed directions provided in the project's Health and Safety Plan.

5.3 DPT Sampling Methodology

There are several methods for the collection of soil samples using DPT drilling. The most common method is discussed in the following section. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project-specific plan.

- Macrocore samplers fitted with detachable aluminum or steel drive points are driven into the ground using hydraulic pressure. If there is concrete or pavement over a sampling location, a Roto-hammer is used to drill a minimum 1.5-inch diameter hole through the surface material. A Roto-hammer may also be used if very dense soils are encountered.
- The sampler is advanced continuously in 4-foot intervals or less if desired. No soil cuttings are generated because the soil which is not collected in the sampler is displaced within the formation.
- The sampler is retracted from the hole, and the 4-foot continuous sample is removed from the outer coring tube. The sample is contained within an inner acetate liner.
- Attach the metal trough from the Geoprobe® Sampling Kit firmly to the tail gate of a vehicle. If a vehicle with a tail gate is not available, secure the trough on another suitable surface.
- Place the acetate liner containing the soils in the trough.

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- While wearing cut-resistant gloves (constructed of leather or other suitable material), cut the acetate liner through its entire length using the double-bladed knife that accompanies the Geoprobe® Sampling Kit. Then remove the strip of acetate from the trough to gain access to the collected soils. Do not attempt to cut the acetate liner while holding it in your hand.
- Field screen the sample with an FID or PID, and observe/examine the sample (according to SOP GH-1.3). If appropriate, transfer the sample to sample bottles for laboratory analysis. If additional volume is required, push an additional boring adjacent to the first and composite/mix the same interval. Field compositing is usually not acceptable for sample requiring volatile organics analysis.
- Once sampling has been completed, the hole is backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch is used to cap holes through paved or concrete areas. All holes should be finished smooth to existing grade.
- In the event the direct push van/truck cannot be driven to a remote location or a sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with battery/electric operated equipment (e.g., jack hammer).
- Sampling equipment is decontaminated prior to collecting the next sample.

6.0 GROUNDWATER SAMPLING PROCEDURES

6.1 General

The most common methodology for the investigation of groundwater is the installation and sampling of permanent monitoring wells. If only groundwater screening is required, the installation and sampling of temporary well points may be performed. The advantage of temporary well point installation using DPT is reduced cost due to no or minimal disposal of drilling cuttings and well construction materials, and shorter installation/times sampling.

Two disadvantages of DPT drilling for well point installation are:

- In aquifers with low yields, well points may have to be sampled without purging or development.
- If volume requirements are high, this method can be time consuming for low yield aquifers.

6.2 Sampling Equipment

Equipment needed for temporary well installation and sampling using DPT includes, but is not limited, to the following:

- 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point
- Connecting rods
- Roto-hammer with 1.5-inch bit
- Mechanical jack
- 1/4-inch OD polyethylene tubing
- 3/8-inch OD polyethylene tubing
- Peristaltic pump
- Standard decontamination equipment and solutions

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6.3 DPT Temporary Well Point Installation and Sampling Methodology

There are several methods for the installation and sampling of temporary well points using DPT. The most common methodology is discussed below. Variations of the following method may be conducted upon approval of the Project Manager in accordance with the project specific plan.

- A 2-foot x 1-inch diameter mill-slotted (0.005 to 0.02-inch) well point attached to connecting rods is driven into the ground to the desired depth using a rotary electric hammer or other direct push drill rig. If there is concrete or pavement over a sampling location, a Roto-hammer or electric coring machine is used to drill a hole through the surface material.
- The well point will be allowed to equilibrate for at least 15 minutes, after which a measurement of the static water level will be taken. The initial measurement of the water level will be used to assess the amount of water which is present in the well point and to determine the amount of silt and sand infiltration that may have occurred.
- The well point will be developed using a peristaltic pump and polyethylene tubing to remove silt and sand which may have entered the well point. The well point is developed by inserting polyethylene tubing to the bottom of the well point and lifting and lowering the tubing slightly while the pump is operating. The pump will be operated at a maximum rate of approximately 2 liters per minute. After removal of sediment from the bottom of the well point, the well point will be vigorously pumped at maximum capacity until discharge water is visibly clear and no further sediments are being generated. Measurements of pH, specific conductance, temperature, and turbidity shall be recorded every 5 minutes during the purging process. After two consistent readings of pH, specific conductance, temperature and turbidity (± 10 percent), the well may be sampled.
- A sample will be collected using the peristaltic pump set at the same or reduced speed as during well development. Samples (with the exception of the samples to be analyzed for volatile organic compounds, VOCs) will be collected directly from the pump discharge. Sample containers for VOCs will be filled by (first shutting off the pump) crimping the discharge end of the sample tubing when filled, removing the inlet end of the sample tubing from the well, suspending the inlet tubing above the vial, and allowing water to fill each vial by gravity flow.
- Once the groundwater sample has been collected, the connecting rods and well point will be removed from the hole with the direct push rig hydraulics. The hole will be backfilled with bentonite chips or bentonite cement grout, depending upon project requirements. Asphalt or concrete patch will be used to cap holes through paved or concrete areas. All holes will be finished smooth to existing grade.
- In the event the direct push van/truck cannot be driven to a remote location or sampling location with difficult accessibility, sampling probes may be advanced and sampled manually or with battery/electric-operated equipment (e.g., jack hammer).
- Decontaminate the equipment before moving to the next location.

7.0 RECORDS

A record of all field procedures, tests, and observations must be recorded in the field logbook, boring logs, and sample log sheets, as needed. Entries should include all pertinent data regarding the investigation. The use of sketches and field landmarks will help to supplement the investigation and evaluation.

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ATTACHMENT 1
SAFE WORK PERMIT FOR DPT OPERATIONS

Permit No. _____ Date: _____ Time: From _____ to _____

SECTION I: General Job Scope

I. Work limited to the following (description, area, equipment used): Monitoring well drilling and installation through direct push technology

II. Required Monitoring Instruments: _____

III. Field Crew: _____

IV. On-site Inspection conducted ☐ Yes ☐ No Initials of Inspector TINUS

SECTION II: General Safety Requirements (To be filled in by permit issuer)

V. Protective equipment required Respiratory equipment required

Level D <input checked="" type="checkbox"/> Level B <input type="checkbox"/>	Full face APR <input type="checkbox"/>	Escape Pack <input type="checkbox"/>
Level C <input type="checkbox"/> Level A <input type="checkbox"/>	Half face APR <input type="checkbox"/>	SCBA <input type="checkbox"/>
Detailed on Reverse	SKA-PAC SAR <input type="checkbox"/>	Bottle Trailer <input type="checkbox"/>
	Skid Rig <input type="checkbox"/>	None <input checked="" type="checkbox"/>

Level D Minimum Requirements: Sleeved shirt and long pants, safety footwear, and work gloves. Safety glasses, hard hats, and hearing protection will be worn when working near or sampling in the vicinity of the DPT rig.

Modifications/Exceptions.

VI. Chemicals of Concern	Action Level(s)	Response Measures
_____	_____	_____

VII. Additional Safety Equipment/Procedures

Hard-hat <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Hearing Protection (Plugs/Muffs) <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Safety Glasses <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Safety belt/harness <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Chemical/splash goggles <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	Radio <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
Splash Shield <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No	Barricades <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Splash suits/coveralls <input type="checkbox"/> Yes <input type="checkbox"/> No	Gloves (Type - _____) <input type="checkbox"/> Yes <input type="checkbox"/> No
Steel toe Work shoes or boots <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	Work/warning regimen <input type="checkbox"/> Yes <input type="checkbox"/> No

Modifications/Exceptions: Reflective vests for high traffic areas.

VIII.

Procedure review with permit acceptors	Yes <input type="checkbox"/> NA <input checked="" type="checkbox"/>	Emergency alarms	Yes <input type="checkbox"/> NA <input type="checkbox"/>
Safety shower/eyewash (Location & Use).....	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA	Evacuation routes	<input type="checkbox"/> Yes <input type="checkbox"/> NA
Daily tail gate meetings.....	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> NA	Assembly points	<input type="checkbox"/> Yes <input type="checkbox"/> NA
Contractor tools/equipment/PPE inspected.....	<input type="checkbox"/> Yes <input type="checkbox"/> NA		

IX. Site Preparation

Utility Clearances obtained for areas of subsurface investigation	<input type="checkbox"/> Yes <input type="checkbox"/> No
Physical hazards removed or blocked	<input type="checkbox"/> Yes <input type="checkbox"/> No
Site control boundaries demarcated/signage	<input type="checkbox"/> Yes <input type="checkbox"/> No

X. Equipment Preparation

Equipment drained/depressurized	Yes <input type="checkbox"/> NA <input checked="" type="checkbox"/>
Equipment purged/cleaned	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA
Isolation checklist completed	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA
Electrical lockout required/field switch tested	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA
Blinds/misalignments/blocks & bleeds in place	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA
Hazardous materials on walls/behind liners considered	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> NA

XI. Additional Permits required (Hot work, confined space entry). ☐ Yes ☐ No
If yes, complete permit required or contact Health Sciences, Pittsburgh Office

XII. Special instructions, precautions:

Permit Issued by: _____ Permit Accepted by: _____